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Scientific Methods in the Study of Handwriting.

In the view I have adopted for treating this theme, by handwriting is meant any symbols, characters, signs, or marks, graven, scratched or stained on any object, by means of which ideas can be conveyed from one living thing to another.

This definition is purposely made broad enough to cover hieroglyphics on stone, writing on papyrus, and even the tramp-like or American Indian-like signs by the mere breaking off of twigs, or the scratching of bark for the purpose of informing or warning some other living being.

You will notice I have put living being instead of man or person, for who can doubt that many of the creatures we regard as lower animals thus communicate with each other? It were hard otherwise to account for their often noticed avoidance of a spot where one of their number has been captured or injured.

You will naturally inquire whether I believe that the "handwriting" which consists in nibbling off blades of grass or break-

ing twigs can leave signs of authorship capable of detection. Although it leads us temporarily away from the real subject I propose to treat to-night I will answer "yes," and the reasons I adduce will furnish a very good introduction to the thesis I shall try to sustain:—

If we regard any physical act of a conscious living being whether human or unhuman, it resolves itself into (1) a picture in the mind of a certain condition of things; (2) the will to make a change in those conditions; (3) the peculiar mechanism by which it must effect this object; (4) the expenditure of the necessary power to produce motion in the mechanism to bring about this change; (5) the guiding of this instrument by intelligence to perform the necessary motions. There are here five elements required to accomplish the simplest act. Not only is this the case but in living beings four of them, the thinking, willing, production of power, and exercise of direction, fluctuate continually during very minute intervals of time, and the instrument itself changes in efficiency though generally more slowly; so that if we had the means of representing each of these elements by a symbol indicating its efficiency (that is its strength or weakness, perfection or imperfection in any act accomplished by the combination of all four), we should almost certainly find one or more and possibly all of these values changed in any repetition of that act.

This change, however slight, would affect their relations to each other and would inevitably cause some change in the result.

If this be true it is a sufficient explanation of the conceded fact that no two things can be made exactly alike. And this is not astonishing when we reflect that these five elements above mentioned represent the conditions due partly to psychical and partly to physical forces, for even when the conditions are purely physical, as in the production of a heap of sand below the narrow tube of an hour glass, or the condensation of a drop of water from moist air on a cool surface, only a sufficiently minute scrutiny is needed to detect differences between any two heaps made in the same hour glass, or any two drops condensed from the same steam on the same surface.

It may then be assumed that no living thing can exactly duplicate any act it may have performed, nor can such exact duplication be obtained by mechanical means; yet each act will

produce in the result characteristics distinguishing it from the acts of all other agents.

Confining ourselves, as the limit of time demands, to marks of human beings conveying intelligible ideas to each other, it seems reasonable to guess that the first of such signs were the simple blazing of trees or the making of marks conveying directions or warnings. And if we may be guided in our belief of the sequence of events in those prehistoric times by that in the period of which we have records, it is probable that hardly were those rude signs invented to guide, before they were perverted to mislead, their ignorant readers, whether enemies or dupes.

So it must have been with the subsequent improvement in conveying ideas through chiseled stone and stained papyrus by imitations of the objects which the paleolithic artist saw around him, and thence on to ideograms having a conventional meaning. Who doubts that the admiring slave, cutting the record of the deeds of his adored Sovereign on the obelisk of Syenian granite added a few more men or birds to his history than the facts justified, and thus inaugurated a system of necrological mendacity which has become a proverb, almost universally illustrated on tombstones even to the present day?

But it was not exclusively pious lying which engaged the ingenuity of early man, but falsification for gain. To suppose that some beneficiary of the generosity of Joseph did not raise the order of the Israelite Governor of Pharoah's granary for corn; or that the architects and contractors of Solomon's Temple did not accept any payment for air and no time; is to make dishonesty too young.

Gradually as the system of life became more complicated the best chiseler, scratcher, or marker would become the head man's scribe, and his records would be more valuable because official. As soon as such a difference of value manifested itself, and there was an advantage in making a record appear to be official, the first forger appeared.

He studied the peculiarities of the official marks and tried to imitate them, and thus obtained more women, cows, or cocoa nuts, than his more ignorant and innocent fellows.

The above sketch of the origin of handwriting and its misuse is purely imaginary though probable, but it is unquestionable that in Thebes, Memphis, Sparta, Athens, Syracuse, and Babylon,

manuscripts were scratched, re-surfaced, and bleached with skill; some passages suppressed and others added, with the result that the writing thus tampered with was either garbled or even frequently made to assert the contrary of its original text. These frauds were, for prudential reasons, usually perpetrated on the works of the dead.

*Eusebius is suspected of having added to the original text of Josephus (who died in the year 95) the oft cited paragraph which confirms certain statements of the Evangelists. St. John himself, by the imprecation appended to his Apocalypse on the head of whomsoever should "take away from the words of the book of this prophecy" (Rev. xxii, 19,) shows how prevalent the crime of forgery was in his day.

Erasmus complained that among all his manuscripts he did not possess a single text which had not been falsified.†

The commerce of falsifying documents begat the art of detecting the falsification, but as in all first attempts to separate the true from the false, and parallel to all previous attempts by man to separate objects into classes, the conclusions were based on merely superficial appearances.

For instance, the great Aristotle's "elements" consisted of fire, water, heat, and cold. All things were fashioned out of them.

In his "History of Animals" he says, "Some animals are aquatic, others live on land * * * Some land animals inhale and exhale air * * * others, like the wasp and bee, do not * * * some obey a leader, others are anarchical * * * the stork and bee are in the first class, the ant, &c., in the latter."

* * * "some animals hunt their food, others not; some are troglodite(lizards and serpents), others not. * * * There are tame and wild. *Man and the mule are in the former class.* (Italics the quoter's.) * * * Some utter a loud cry others are silent. * * * All animals possess in common those parts by which they take in food and those into which they receive it. There is only one sense of touch common to all animals. * * * some have feet, others not. Some winged have feet like eagles and hawks, others like the cockchafer and bee.

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*Of Pamphili of Cæsarea b. 265 A.D. not he of Nicomedia.

†See on this subject "Le faux devant l'histoire &c" Gustave Itasse. Paris,

* * * All which are bloodless (except a few marine cephalopoda) are smaller than those with blood."

"The following are the principal classes: birds, fishes, cetacea;—all these have red blood. There is another class covered with a shell without blood. There are no large classes of other animals."(!)

He and much humbler followers sought to distinguish objects by color and form (changeable), or by habits and cries (often imitated), in other words by purely superficial and trivial features. Yet if a number of these trivial peculiarities co-exist in a single specimen the chance of error is very small. Thus a stout little feathered ovoid with strong short legs, a white speckled breast, a white streaked neck and a short beak, which runs under one's feet with a whirring sound, and pipes from the distant corner of a field or woods "Bob White," may be set down as what is called in Pennsylvania a partridge as certainly as if the anatomist had examined its skeleton and soft parts. But that is only because there are enough separate characteristics to establish identification.

Suppose a sportsman to come upon a dead bird and attempt to name it from its form and color only. If both be normal he probably will not fail; but if, as often happens, one of the elements be not normal; the color and spots absent, or the shape of the bird unusual, he would apply to his friend the ornithologist, who on dissecting the parts would assign the object to its proper genus and species. The case is analogous to the study of handwriting. From the earliest times to the present the determinations have most frequently been based upon the more or less trivial and accidental superficial appearances, and this has made the occupation of handwriting expert the nest of ignorant and unscrupulous charlatans, because unproven opinions were remunerated, and the assertion of an opinion cannot be denied to the most ignorant and venal.

A history of the study of handwriting is not easy to obtain.

In treating the subject of this lecture it is unfortunately unavoidably necessary to pay what must seem exaggerated attention to "experts" past and present because although most of them have never employed scientific methods, they constitute the only class which has dealt with the analysis of handwriting, the

calligraphers, illuminators and writing masters having confined themselves to its construction or synthesis.

Under the general heading of "Psychology" in the Revue Scientifique (Revue Rose. No. 25, 4th Series, Vol. VIII, 18th Dec., 1897, p. 769.) is an article by Alphonse Bertillon on "The comparison of writings and graphic identifications." Over the opening words is a quotation from "Vallain écrivain—juré—expert" to the effect that "One must not neglect too much the proof by comparison of writing nor hold it too slavishly. It is the part of prudence in the judges to give it as much credence as seems good to them."

After extolling the services of the Prefecture of Police in Paris, and his own cleverness in discovering the identity of the false Rabardy, perpetrator of the dynamite explosions in the Rue St. Jacques and St. Martin, with the anarchist who killed himself by the explosion of a bomb on the porch of the Madeleine, M. Bertillon states that in the last century the Lieutenant of Police was President of the Academy of master-sworn-expert-writers, to which no one could belong who had not given a specimen of calligraphy. Still the criticisms of these were much the same as to-day. A certain Raveneau 1656 (whose only predecessor was Damelle in 1609) wrote, says Bertillon, the most complete treatise on the subject up to the present time. He complained of the lack of science of his colleagues which, little or great however, put him into jail for forgery shortly afterwards. Robert Prud'homme (1639), de Bligny (1699), Vallain (1761), d'Autrèpe (1770), and Jumel (1790), are the only authorities he finds in the XVIIIth century.

In the XIXth century he mentions an essay by Saintomer (1832), a little work by Levéque (1840), and a pamphlet (1880) on "The vicious method of expertism in writing" by the Abbé Michon, the founder of "Graphology," concerning which Bertillon remarks, "Here, on the part of the old Abbé, is a method, very questionable and very little Christian, to use occultism for the moral examination of an accused before a court of Justice." Vogt (1880), "Handwriting from the physiological point of view;" Javal, "The mechanism of writing" (1881); A. Binet, "Various very interesting studies published in the bulletin of the laboratory of experimental psychology." Finally he is

good enough to add, "Frazer, United States, 1894. The only scientific work on the subject."

In a MS copy of d'Autrèpe it appears that the Academy of sworn-expert-writers over which he presided kept on hand the best executed forgeries for the purpose of submitting them to the candidates. M. Bertillon concludes that forgeries were much commoner in the past ages than to-day.

Under the existing laws governing these experts in handwriting it is the duty of the first President to inscribe five for the Tribunal of the Seine and all the numerous experts employed by the courts; but this list does not exclude a Magistrate from calling one not thereon inscribed.

Of the experts in, 1897, M. Gobert was formerly a bank clerk and expert chemist; M. Belhomme, formerly of the University; M. Pelletier, a remarkable calligraphist attached to the Ministry of Fine Arts, and M. Varinard, an ingenious adept in Graphology. Besides these are M. Teysonnière, and M. Charavay, archivist and paleograph, both well known. An admirable little book on "Le Faux devant l'Histoire," etc., by Gustave Itasse, appeared in the year following Bertillon's article (De la Grave, Paris, 1898.)

In Germany neither the experts in handwriting nor the critics are wanting. In special branches of the main subject of Bibliotics Germany has furnished, as in so many other branches of applied science, the most valuable contributions. Thus Sittl, of Munich, has contributed important suggestions for determining the fact and the character of alterations in parchments, and the relative ages of parchments and inks; Neumann and Schluttig have given valuable contributions on the manufacture of inks; and there are many others.

Among the sworn judicial handwriting experts W. Langenbruch, of Berlin, who, with the coöperation of Sanitation Counselor, Dr. A. Erlenmeyer, of Bendorf on the Rhine, and Professor Dr. W. Preyer, formerly of Wiesbaden, issued a monthly sheet called "Die Handschrift" (or "Handwriting") from April to December inclusive, 1895; which contained some interesting contributions and illustrations. At the end of the last number, however, appeared the significant notice that at the close of the year 1895 "by mutual agreement of Editor and Publisher its appearance would be discontinued." In the first number occurs a

sharp criticism of M. Bertillon's then newly announced discovery of pulse-beats in handwriting by means of which he was said to have proved Dreyfus to be the author of the bordereau after two experts had declared it, in their opinion, not to have been written by the hand of the now famous artillery Colonel; one declared that he could not form a definite opinion; and the fourth believed Dreyfus to be the author.

The convincing effect of M. Bertillon's argument upon the court induced M. Langenbruch to try the experiment upon several specimens of natural handwriting magnified to eighteen diameters, but "the exact, wearisome experiment upon the projected characters led to an entirely negative result." The magnification of objects for the purpose of judging of their genuineness is most frequently like raising the voice to make a foreigner understand you.

Throughout all the discussions in the journal the assumed foundation for Graphology is everywhere apparent, as is the same assumption of the French experts that there is nothing in any handwriting so characteristic and individual as not to be found in some other. German transcendentalism, or perhaps its supposed origin in Goethe and Lavater, may account for this attitude towards Graphology. It is certainly not indicative of ignorance, for we find Prof. Preyer the author of a considerable work in that year on the "Psychology of Handwriting."*

*(Zur Psychologie des Schreibens etc. Von W. Preyer Hamburg und Leipzig. Verlag von Leopold Voss, 1895), a work full of painstaking observations on the method of producing writing, but also of the mysticism of Graphology. After mentioning the monthly French publication "La Graphologie," the "Histoire de la Graphologie," by Emile de Vars, and the "Traité pratique de graphologie," by Crépieux-Jamin, with approbation, he adds, " * * Germany furnishes only very few original works in this practically and theoretically extraordinarily important department."

Among these he mentions the examinations of Langenbruch, the head of the Graphological Bureau of Berlin.

Dr. August Diehl, of Heidelberg, has published a valuable treatise on the "Peculiarities of the writing of the healthy" (Leipzig. Engelmann, 1899).

German authors whose works on this subject are not highly valued by Preyer are "Die Graphologie" (Schweidland Berlin 1883); "Die Handschrift und ihre charactersistschen Merkmale" (Scholz, Bremen 1885); "Beurtheilung seines Charakters, seiner Anlagen u. s. w. nach der Handschrift" (Schumann, Leipzig. Fischer 1883); "Über Graphologie" (Machmer, Zürich, 1889;) "Das Handschriftenlesebuch" &c (Henze 1854): and "Die Chirogrammatementie (id 1862).

Messrs. Charles Chabot and F. G. Netherclift were famous English experts in 1871, in which year appeared a monumental volume by the Hon. Edward Twisleton on the comparison of the handwriting of Sir Philip Francis and Junius.

Mr. Hardless fulfils the duty of Government expert for Great Britain's Indian possessions in Bombay at the present time.

Points of View.

Of the principal points of view from which handwriting has been regarded, the oldest is purely physical and concerned with superficial or pictorial features. One of the more modern dates from the Abbé Michon in 1880 and occupies itself exclusively with the interpretation of handwriting into a description of character. As to this latter it has been very recently thoroughly analysed by a master and one of the founders of psychological experimentation, Dr. Alfred Binet, Director of the Laboratory of Psychological Research in the Sorbonne, who is a friendly investigator. We owe to him "The philosophy of reasoning," "Experimental researches in hypnotism" (1886), and many late valuable studies. It would take too long to explain here his methods, for which the student is referred to his "Révélations de l'écriture d'aprés un controle scientifique," or to a review of this book published in "Science" of October 5th last. Suffice it to say that selecting the best graphologists in France, among whom M. Crépieux-Jamin is incontestably the foremost, he subjected them to a series of tests in determining from writings unknown to them the sex, age, intelligence, and character of the writers. While testing the professional graphologists he submitted the tests to persons both intelligent and unintelligent but entirely ignorant of the alleged new art. Of course the greatest ingenuity and care were taken to avoid the vitiation of results by what Dr. Binet calls "that cholera of psychology—suggestion."

In determining sex from writing the best graphologist made 21 p.c. of errors, and four instructors and instructresses in the schools entirely ignorant of graphology but 27 p.c.

In determining age the best graphologist's determinations were only about 5 p.c. better than if his answers had been dependent on the tossing of a coin.

In determining intelligence Dr. Binet submitted to each graphologist two writings, one of a distinguished thinker and the other of a man of very moderate intelligence. One graphologist

determined the great mathematician Bertrand from his writing to be "destitute of a clear view of things." Dumas, the world famous chemist, was described as having "mediocre intelligence." Brown-Séquard, "intelligence below the average." Rénan, "moderate intelligence but little cultivated."(!) Even Crépieux-Jamin rated Rénan as a "fine mind without attaining talent." But the most ludicrous results were reached in the efforts of the graphologists to read character in handwriting. The handwriting and complete history of each of a number of vile murderers was secured.

The first of these was an assassin whose practice was to waylay and murder women for the few pennies they had on their persons.

(The picture of this depraved wretch, Vidal, reproduced from Dr. Binet's book to illustrate his graphologically given character, was thrown on the screen. His features were coarsely masculine and brutal.)

This is what M. Vié, the second graphologist in France, has to say of Vidal's character judged by his writing:

"The writing is of a young girl of temperate character. She is not sentimental, though capable of affection and altruism, but controls her emotions. * * * Her principal desire to please is natural to her elevated tastes. * * * She does not exaggerate modesty. She is timid because her lack of impulse does not permit her frankness to follow its natural course. Moderation is her motto. * * * She has imagination not without grace. Most surprising is it that her intelligence, diffuse in most young girls, is distinguished by concise and very condensed sobriety," &c.

Another distinguished expert, M. Eloy, who hits upon the right sex, says of the same murderer: "He is nervous & susceptible. His effort to mask this shows tenderness of heart. * * * He is delicate * * * very young * * * and of a sensitive nature!" Here follows from M. Eloy a passage which must have been especially pleasing to the experimenter—Dr. Binet.

"I have felt almost from the beginning," he writes to Dr. Binet, "that this writing was by M. Binet at the age of 15 to 18. Is this the fact?"

The next murderer, Carron, killed his mother to steal her few francs and jested of her death-agony before the magistrate.

(His picture, also photographed from Dr. Binet's book, was thrown upon the screen.)

M. Vié says of this writing: "Young & feminine, a young girl wrote it. * * * She is pleasantly airy. * * * Gentle, modest, and not coquettish. * * * Of loving nature she possesses a guarded affection. * * * Her moderated imagination does not rest on the blue clouds in which the dreams of young girls delight. * * * She is tenacious of truth, and very apt to attach herself to an object if it come to her." * * *

These are merely a few of the most grotesque failures. In many cases the answers were of a kind which Dr. Binet called a "passe partout;" Delphic utterances ingeniously framed to suit any case, with greatest emphasis on points which cannot be determined.

Without attempting to predict what may be the future of graphology, it may be said that at present it has no greater claim to the title of a science or an art than has astrology, according to the results of this very thorough examination by a friendly investigator.

Scientific Methods.

As yet the application of scientific methods to the study of handwriting has not been mentioned. These may be of two kinds, the one simply intended to furnish information on one or more points of a particular case, and the other to supply a basis for a systematic analysis of handwriting. The instances of the first use of science are innumerable and have been made in nearly every case where a scientific man has been asked to aid in an investigation of this sort. The second kind of application is experimental psychology pure and simple.

It has been stated that from the earliest times the methods used by connoisseurs in judging of works of art were employed by handwriting experts. The expert looking at the genuine and a suspected piece of handwriting; comparing them; holding them at a distance; bringing them close to the eyes; inclining the head first to one side and then to the other; used to say that in his opinion they were or were not by the same hand; and if pressed for a reason gave it as "an indefinable something."

Later the examiners compared the minute details of characters and found bases for their decisions on the curls, crossings, dots, and shadings, etc.

During the last century many questions as to authenticity were settled by applications of science and common sense.

Special application of scientific methods.

Thus in the sixties of the last century there was a will purporting to be signed by Sylvia Ann Howland which was examined by Professor Benjamin Peirce, of Harvard, perhaps the greatest mathematician this country has ever produced. He measured the geometrical positions of 30 downstrokes in 42 unquestioned signatures and found 5325 coincidences of position in two signatures out of 25830 comparisons, say 1 in 5. Comparing the two disputed signatures with one genuine he found all the 30 downstrokes coincided.

By the calculus of probabilities he deduced the chance of these 30 coincidences occurring simultaneously to be one in 2,666,000,000,000,000,000,000 times. Of this result he said: "This number far transcends human experience. So vast an improbability is practically an impossibility, less than those least things which the law cares not for." * * *

"The coincidence must have had its origin in an intention to produce it: i. e. it was a forgery by tracing."

Some five years ago an alleged will of four pages, each bearing a signature, was submitted to examination. As the measurements coincided the four signatures were photographed on separate gelatine films and will here be exhibited on the screen, first separately and then superposed.

(Photographs of four signatures on the four pages of a certain will, and photographs of these when superposed were shown.)

My friend Prof. Hallett of the University of Pennsylvania applied the calculus of probabilities to the exact correspondence of three out of the four dots over the "i" in the last name when the four signatures on transparent films were superposed, without considering at all the equally exact correspondence of many other important parts of the four signatures, which would have increased his denominator by several millions.

Dividing the field into a checker board of squares each as large as the diameter of the dots he found that the probability of coincidence of the three dots was $(21 \times 15)^3 = 1 \div 31,255,875$.

To get a conception of this number suppose a signature to be written every 15 seconds (or four signatures a minute): then the time necessary to arrive at this coincidence, writing day and night without intermission would be 148.6 years.

Another application of common sense to the detection of forgery was made by Sittl, of Münich, who found on the paper of a document dated 1868 a water mark representing the eagle of the present German Empire which did not come into being until after the war with France in 1870.

Another such application of common scientific sense happened during the famous trial of the Whitaker Will in this city. A will presented for probate at Mr. Whitaker's death in 1878 professed to have been written in 1875, and the ink marks were of that rusty brown color which is frequently noticed in writings of that age and over, due to the oxidation of the iron which is an important ingredient of ordinary inks. The best imitation of this color is a pigment or paint never used for a writing fluid, which contains practically no iron. It occurred to the chemist who first saw the paper that a test for iron in the written characters of the will would show whether the change of color was natural or merely imitated, and it proved to be the latter.

Dr. Chas. A. Doremus showed by a fluoresence test that a writing dated in 1862 was written with Eosine ink, and as Eosine was not discovered till eight years afterwards, the writing was necessarily a forgery.

Similarly an examination of writings by transmitted light and photographs of them show markings and differences between the parts which are not visible to the naked eye.

Dr. Stéphane Minovici, Professor at the University of Bucarest and chemico-legal expert, in a paper read before the 4th International Congress of Applied Chemistry, held in Paris, July 25, 1900, has collected together a number of cases where photography has aided in the detection of, or satisfactorily demonstrated falsifications of writings.

Colorimeter.

Another device for determining questions which may be of

value in an investigation is a colorimeter for fixing what is called the color value of inks. No ink is really black and most inks are distinctly mixed with some coloring matter, usually blue, but almost all inks show more or less yellow and red also. Let us for simplicity consider white light to be composed of red, yellow, and blue rays.

When a fluid ink is traced upon paper it evaporates and leaves on the surface an extremely thin layer of colored material which it previously held in solution. White light falls upon this film and in traversing it loses a very small part of its constituent rays by absorption. Thus the substance in the ink which appears to our eyes blue does so because it absorbs more of the red and yellow rays, allowing proportionately more of the blue ray to escape: the yellow constituent absorbs the blue and red rays most completely and allows more yellow to escape; and similarly the blue ray absorbs the red and yellow.

In ordinary illumination the light traverses the film twice, once in its downward path to the paper, and when reflected from the underlying paper, again through the ink film to the eye. It suffers two absorptions and reaches the eye deprived of a very small part of the rays of the original beam. But this very small loss unless divided equally between the three rays will disturb the balance of colors and the light which reaches us will be reddish, yellowish, or bluish, if the disturbance be sufficient to affect the sight. In ordinary cases it is not sufficient and some artificial device is necessary to ascertain the change which has taken place.

For this purpose I have used three small prisms of red, yellow, and blue glass respectively. If in turn the thin edge of each of these prisms be placed over an absolutely black line, by pushing the thick end towards the line the whole field of the paper, colored by the particular prism used, will grow darker the greater the thickness, but the line cannot grow darker if it be, as supposed, absolutely black from the first. In this case the color value of the ink would be Red 0, Yellow 0, Blue 0.

But if the line to be measured emit the least trace of color—say yellow, the conditions will be changed. When the red and the blue prisms, both of which absorb yellow light, are passed successively over the line the latter will be observed to darken, up to a certain point which may be read on a scale underneath. If

the prism edge be pushed beyond this point the whole field of view darkens equally with the line simply because the greater thickness of glass at the base of the wedge or prism is cutting off more light. At the point where the line ceases to grow dark more rapidly than the field on which it appears, the number of units of the scale is read off and noted as an empirical red color-value for the ink. The same process being applied by the aid of the yellow and blue prisms, the empirical color-value of the ink for a given illumination is noted: Say as R—7, Y—35, B—11.

Another ink line being subjected to the same examination if the values agree closely one may conclude from the physical to the chemical similarity of the inks with a very high degree of probability. If the proportion of color-values disagree it may be safely assumed that the physical and therefore the chemical constitution is different. In fact without in any way injuring the writing, the test gives as much information of value in determining agreements or differences, as a chemical test.*

(Measurements of lines drawn on glass with standard inks were made on the screen by projecting a millimeter scale under them and passing the colored prisms across the field.)

Another useful device for determining which of two lines is above and which beneath depends upon the fact that when light falls upon a surface at a very acute angle it is totally reflected and reveals the true outline of the surface of a mark on which it falls, no matter how transparent the film composing that mark may be.

If a very black ink line underlie a very pale one it will be impossible by looking down on it to determine which of the two is uppermost. But when illuminated by light falling very obliquely to the surface the order in which the lines have been traced becomes perfectly apparent.

(This was shown by an experiment with two strips of differently colored glass bound together at their intersection and obliquely illuminated by the lantern beam.)

The extent to which the writing of one person may be modified by another grasping the same pen is an extremely interesting study. I have published papers on this subject in the Proc. Am.

*The City of Philadelphia awarded the John Scott medal to the deviser of this colorimeter.

Phil. Soc. and elsewhere, but it would take too much time to discuss the subject here. From the results of experiments undertaken it is by no means impossible that a minute examination of such joint writing may frequently suggest the two persons concerned in making it.

But a simple case of joint marks is given in two photographs on the screen. (Fig. 1.) It was claimed that in both cases the hand of the person whose mark was being made touched the pen handle while another person made the mark. 3500 crosses were made and studied under the microscope by me without finding a

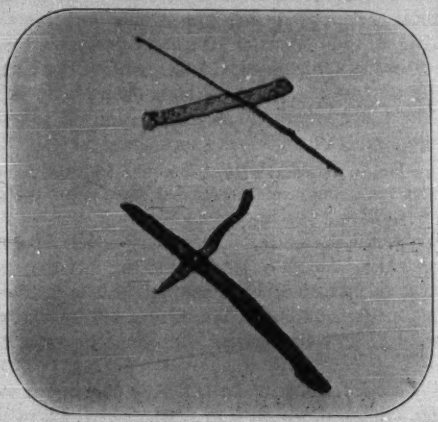


Fig. 1. The upper cross was made without the touch of a second hand on the pen holder. In the lower figure the pen holder was touched by another hand.

single exception to the rule that one or both margins of the line so made were crooked and irregular, and one margin continuously so.

A very interesting study of the effect of rotating a pencil in the hand to supply a fresh point when the first point is abraded, and the different directions of rotation employed by different writers is illustrated on the screen. The words "J. L. Morton, Boston, Mass.," were found written on a piece of paper without further mark.

The pencil writing of a person suspected of being the writer of

these words was examined under the microscope, and tracings of parts of the pencil line of each were made, and are shown on the screen. (Fig. 2.) A surface of paper is not really smooth as it seems to be, but is composed of fibres which stand up somewhat as the stalks of grain in a wheat field, and this is the most evident the less the amount of sizing or surfacing has been used. When a pencil point commences to write it is soon abraded to a flat sur-

Fig. 2. Partial tracings of pencil marks made by two persons. In the two upper marks the writer rotated the pencil to the right as is shown by the fragmentary character of the left hand margin of each of the two magnified pencil lines. In the three magnified marks below the fragmentary character is on the right hand side showing that the rotation was to the left.

face which makes a broad and indistinct line. Instinctively writers turn it, some to the right and some to the left, to use the edge or point which has been newly made. In turning it the plane surface extends up from the paper obliquely and smudges the little standing fibres near the line of writing, but this effect becomes less as the distance on the paper from and perpendicular to the line increases, until only a few scattered fibres have their

tops blackened. The side on which this archipelago appearance occurs will depend upon which way the pencil has been rotated. In the writing in question it was on one side and in that of the suspected person on the other.

A decalcomania or composite putting together of letters taken from the writing of this suspected person to form the words J. L. Morton, &c., furnished additional proof that he had not written it.

Application of scientific method to the entire subject of the study of handwriting. Bibliotics.

But all these cases are of individual application. They are tests to determine yes or no as to a single question which may or not be sufficient to prove tampering or alteration. Every case of any kind must offer opportunities for this sort of exercise of common sense. Every man who walks the street does so presumably with sufficient intelligence to enable him to surmount a coal chute which may bar his way and which he may never have met before or since. Exercise of this kind of intelligence does not approach the subject of the scientific study of handwriting.

Twenty-five odd years ago before the science of psychology had established itself as one of the galaxy of anthropological researches; and before experimental psychology existed, I was led to begin the study of handwriting by methods which are now recognized as those of experimental psychology.

Starting with the observation that many of the concrete results of man's acts reveal their author by appearances due to peculiarities of constitution of his mind or his body let us suppose a person wishes to write a capital "A." He has long before selected the model which he prefers for this letter, and the method of producing this model on paper. Before he makes the first mark he has decided how large the letter shall be. (I mention this because it is unquestionable that the space available, and many other trivial and variable circumstances influence a writer to write larger or smaller letters than his average, and this fact, together with an inherent sense of proportion of one part to another, furnishes an excellent means of detecting authorship as I shall show later).

To accomplish the simplest stroke the person supposed has, first, a mind with functions peculiar to itself, in which the image

of what he is going to attempt is impressed. He has to materialise this model by means of a wonderfully constructed machine consisting of bone levers, tendon joints, and muscle motors, the latter so moving the rigid parts as to make, as nearly as possible, the tracing desired. But no joints are so perfectly fashioned as to work equally well in all directions. In some of the motions necessary to reproduce the design there will be a less flexibility of the instrument than in others, so that some of the many kinds of strokes necessary will be accomplished in a way differing from the normal of the majority of writers. The same is true of the model in the person's mind, even if that model be the image of a design before the eyes, for two pairs of eyes see the same thing differently; and all these circumstances will influence the resulting tracing.

There are in all writings by the same person two features invariably present; the one a constant tendency to reproduce original forms which have become a habit, differing from the forms of other writers and therefore individual characteristics; the other, a modification or omission of one or more of these (usually numerous) characteristics in any given word or letter. These two features are quite analogous to the two biological "laws" which govern the production of plants and animals, called by Darwin those of "heredity" and of "accidental variation." It is therefore indisputable that the best means of identifying the author of a handwriting is to discover what are the constitutional divergences of his handwriting from the usual forms of ordinary handwriting, and to separate these constitutional divergences from the casual variations from them which exist in every specimen from his pen. The surest and most obvious way to do this is to secure from a number of specimens of his writings the average formation of each of the characteristic features.

This may be done in various ways, as I shall later explain, and when accomplished, the sporadic changes from his usual style will be eliminated, and a type secured containing all, or at least most, of his characteristics.

First of all in deciding questions of authorship the need of a standard as perfect as possible is apparent.

Composites.

In 1881 Francis Galton had read a paper before the Photo-

graphic Society of Great Britain, and shortly afterwards published his "Human Faculty" in which the marvelous results in graphic averages representing types, are shown in families, in professions, in disease, and in crime, by composite photographs. For the methods to be employed consult the book just mentioned.

Fig. 3 is a composite of a father, mother, two sons and a daughter.

Fig. 3. Composite of a family of five, two adults and three children.

It occurred to me in the early eighties to apply the principle of composite photography to signatures and thus obtain a type—*the* type—which the writer had always tried to achieve without quite succeeding, by which the doubtful signature could be judged. The composite I produced was a very clumsy result compared to subsequent efforts.

(Various composites of signatures, including that of Clark & Co., the first ever made, were thrown on the screen. Those who are interested will find many examples in "Bibliotics" or "The Study of Documents.")

Measurement, Average, and Ratio.

But as the problems multiplied I found that not all were susceptible of the treatment by composite photography; sometimes because the standards were in large ledgers, or were otherwise difficult to photograph; sometimes because there was not time to prepare the plates. Besides, when the composite was obtained it was only a means to an end, not the end itself. In other words

the task remained of beginning the work of determining genuineness after the composite was secured.

To meet his need I devised the plan of exact measurements of lengths of word, and groups of letters; heights of certain letters in the words; and the calculation of the ratio to each other of these two latter factors. Without knowing it I had invaded the domain which is now that of experimental psychology by using as a method of detection what proves to be an involuntary habit of an intelligent writer, viz: that of enlarging or reducing all parts of a signature to which the writer is accustomed, with much greater approach to exact proportional relation to each other than any other writer can do this even though he be an expert penman and use his best skill. It will often occur that owing to more space to be filled, or less space available, the writer will change the average length of his signature. In doing so he will inevitably reduce the vertical parts of the writing in close proportional conformity to the lengths—whether from an unconscious measure of the relative amount of time employed in tracing each part, or for some other reason does not here matter.

But the result is that very large and very small signatures when "ratioed" become comparable.

A copier of such a signature has not the same apparatus with which to write it, and is entirely ignorant (as indeed the genuine writer may be) of the rhythm, of the allowance of time to accomplishment, which keeps all parts proportional in size. Consequently the simulator will have some parts right and others entirely discordant with them.

An investigation of this kind applied to the writing of Sir Philip Francis and to that of Junius was published by me in 1901; the word "more" being taken (Bibliotics 3d Ed. 1901, p. 146). While the average lengths of this word in 36 instances of Sir Philip and of Junius respectively were as 22.06 to 14.29, or differed about as 3 to 2 (more correctly by 35 p.c.) the ratios of the length to the height of the word written by Sir Philip agreed within 1 p.c. of the same ratio of the same word as written by Junius.

In a more recent study where five genuine and twenty-four disputed words "Mary" and "will" were compared; though the greatest discrepancies existed in actual sizes of the separate words, the ratios of the heights of the letters "r" and "l" to the

lengths of the respective words of the averages in the two groups of each word differed by less than 1.04, and 0.02 p.c. respectively. (Figs. 4 and 5.)

In the last two instances (Figs. 6 and 7) a part or the whole of one dimension is composed of a gap, a sort of graphic cæsura, where the pen leaves the paper while the motion of the hand is continued, the pen point being carried through the air for a cer-

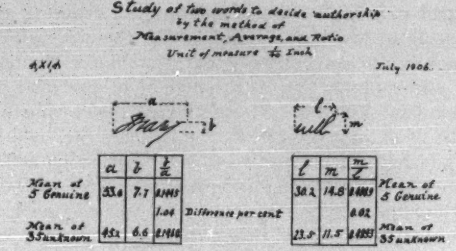


Fig. 4 Fig. 5

Comparison of height to length ratios in two groups of words.

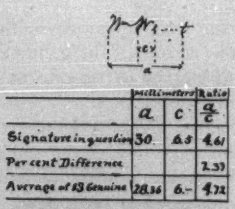


Fig. 6. Ratio of length of word to extent of gap in a [signature compared with the ratio in an average of thirteen others.

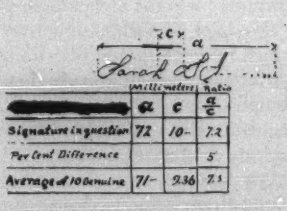


Fig. 7. Comparison of ratio of length of word to width of gap of a signature with the same ratio in ten others.

tain length of time before it is again touched to the paper to continue the record. The extent of this gap and the relative direction of the point of resumption from the point of departure are extremely characteristic of a writer.

The width of the gap is a distance measured by the writer through that imperfectly understood method of measuring time which we all possess, often ascribed to pulse beats: because with the hand in motion the width of the gap will depend on the time the pen is suspended above the paper. Every one will have his

own peculiar intuition of the time to be allowed in order to produce the effect he intends, and every one's appreciation of the necessary time as well as every one's model must differ from those of others.

But that is not all. The word has been mentally cast to fill a certain space; if this space be the normal average of the writer, then the average obtained from a number of such words written by him will give the extent of this discontinuity very closely, but if he has concluded to write the whole word larger or smaller, the dimensions of the gap must be increased or diminished to fill accurately its proportional part of the word.

From a number of experiments, not sufficient however to establish moduli of rapidity for all writers, I have found the pen point to move 17 m m per second in the slowest and 60 mm in the fastest writing I have timed. Illiterate and phenomenal writers would extend the limits downward and upward respectively.

As a result of all this the occurrence of gaps in a line of writing becomes an extremely important and delicate test of identity of authorship.

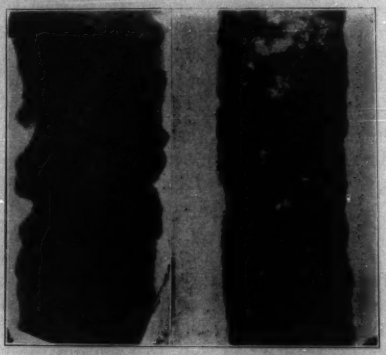
Dr. August Diehl in the very valuable treatise mentioned before on the writing of the healthy, gives tables in which are recorded the lengths of path traversed by the pen in writing the same word on successive trials, and the rapidity of the pen in millimeters to hundredths of a second. He experimented with three writers first writing slowly and carefully, and later fast and without care, on different days and under varying conditions.

His results show that in making a single numeral "8" the path of the pen varied from 11.61 mm. to 13.8 mm., and the rapidity of writing varied from 28.17 mm. per second by the fastest writer of these three persons to 18.76 mm. per second by the slowest. The mean was 23.36 mm. per second. Dr. Diehl (who sent me this book with a very pleasant letter) did not attempt to ascertain the average speed of a large number of writers. The persons upon whom he experimented were four male and four female assistants in the University clinic for the insane at Heidelberg.

There is therefore no discrepancy between his results and mine, but both are insufficient to establish a time average for the writing community.

Tremograms.

Of the same character is a study which is merely begun; that of the curious marginal irregularities which accompany and seem to a certain degree to characterize the handwriting of each writer, which I have called "tremograms." In studying those of different individuals it will be observed that these irregularities differ. (1) in general appearance; (2) in the margin of the ink line on which the greater number of them occur; (3) in the number of these to a unit of length in the ink line; (4) in the rapidity with which lines joining the apexes of the angles on the two margins oscillate up and down from horizontality in a given length of ink line. A few examples are given.



a Fig. 8 b

a—Ink line made by hand, here magnified about 60 diameters.
b—Ink line made by a ruling machine, here magnified 91 diameters. By an error in printing both these figures have the left and right sides transposed.

In the first illustration (Fig. 8) are represented side by side a line drawn on paper by a ruling machine (b) and a portion of a letter written by Prof. Lightner Witmer (a). The machine drawn line is magnified ninety-one diameters and the hand written line about sixty, yet the irregularities on the margins are less on the former than on the latter. By an error in producing the plates the right and left sides of each of these figures are reversed.

The study of Washington's tremograms is from a letter in my possession which he wrote to an ancestor of mine. The ink is

faded in places but in the parts of the "G" represented, age has only accentuated without destroying the tremograms. (Fig. 9.)

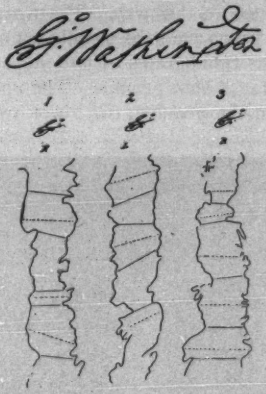


Fig. 9. Three tremograms from the "G" in the above signature. The oscillation of the lines joining the cusps and sinuses from the top to the bottom are observable.

Fig. 10 represents the margins of the ink line as they appear to the eye through the microscope except that the color of ink and paper are reversed. Ordinarily I have used only line tracings of the margins or sides of the ink lines, but I was surprised when an un-

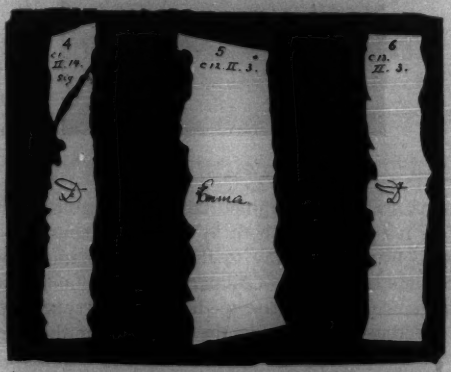


Fig. 10

usually intelligent Assistant District Attorney confessed to me once that he had never clearly understood the tracings until he saw them represented in this way. The marginal tremograms are traced on thick paper and subsequently cut out by a pen knife.

Fig. 11 represents tremograms of two signatures of the same name, to all appearance both genuine. The upper three pairs of margins were from the genuine, the lower two pairs from the

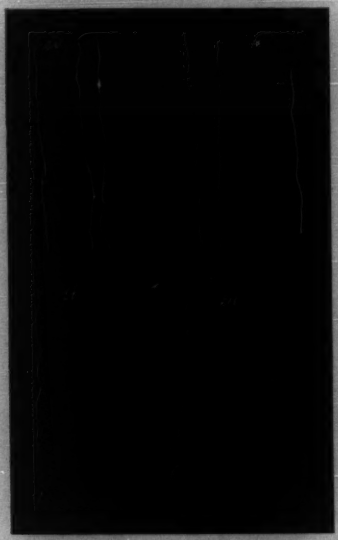


Fig. 11. Tremograms from two signatures pronounced genuine by ordinary tests. The tremograms show them to be by different hands and the lower is a forgery.

forged signature. It was of importance to determine immediately whether or not they were both by the same hand. If not, the forger, who was on his way to the railway station under surveillance, could be arrested. Ordinary tests were unavailing. The two tracings under the microscope here photographed established entirely different characters in the structure of the lines. The culprit was arrested, convicted, and, I believe, confessed.

Fig. 12. This case is a still stronger confirmation of the

value of this method. R's signature had been forged by three conspirators, P, J, and M. The tremograms served to assign to each his share in the transaction. In the case of M he had not been suspected until this test was applied. Subsequently he

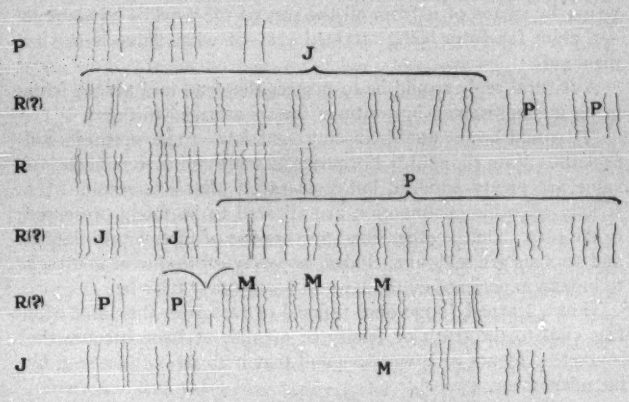


Fig. 12

The above diagram represents the margins of magnified ink lines.

The uneven margins (or tremograms) following the initial letters P, R, & J, respectively, in the left hand vertical column of letters, and those following M on the lower line farther to the right, were drawn from writings unquestionably made by the persons for whom these letters stand.

The tremograms following each of the three symbols, "R (?)," in the left hand vertical column, were made from writings falsely purporting to have been made by R.

The twelve pairs of margins in the second line, under the bracket surmounted by "J," were from writings purporting to have been by R but actually done by J.

The four pairs to the right on this same line were from writings purporting to have been made by R but which really were by P. The four pairs of margins on the fourth line following the second "R (?)" were traced from writings alleged to be by R but which were actually by J; and the twelve following pairs on the same line were from writing pretending to have been made by R but in fact made by P.

In the third line headed by "R ?" (or the fifth line in all) the first four pairs of margins presented as the work of R were from writing produced by P, and the succeeding twelve pairs by M.

Unfortunately the scale is too small to enable one to recognise the analogies of structure of the lines from the same hand between the tremograms of the standards, and those of the simulations of R's writing, especially those by J and M.

The P lines are extremely broad showing heavy pressure on the pen, and very few serrations on either margin. The tremors most noticeable are the smallest, which may be largely due to the constant terrestrial vibrations. It is also difficult to say which margin have the most of these tremors.

In M, on the other hand, and in less degree in J, the tremors are frequent and show sudden changes of direction, but whereas in M the majority of the serrations are on the right side, in J they are about evenly distributed. Perhaps the most sinuous of all the margins are the tremograms of the standard of R, whose writing was simulated by P, J, & M. But these tremors are more serpentine than jagged; and in this, if one might assign nerve action as their cause, we observe what might be expected from the age and debility of the writer.

The last three pairs on the next to the last line (the R ?) should be designated M.

was arrested. The tremograms obtained from authentic writings of R, P, J, and M respectively are placed after those letters.

The tremograms after R(?) are taken from the forgeries of R's name, and in or over each of them is the letter denoting the forger.

Use of the study.

If we concede that the study of this branch of experimental psychology may enable one to detect and chart the peculiarities of handwriting of an individual to the extent of distinguishing the writer by means of it from all the rest of the world's inhabitants —a point far from being attained yet—of what value is this to mankind?

A natural reply would be to protect the dead and absent from being misrepresented by writings falsely ascribed to them.

"It would be invaluable in courts of law" some optimist will exclaim. Vain thought! Forgeries of wills and of certificates of value are plenty enough, but it is rarely that the results of a strictly scientific examination are allowed to be fairly presented to the jury. On the other hand perversions of facts by charlatans and sciolists are seldom excluded, however grotesque or contrary to human experience or the laws of nature they may be.

Thus a learned Judge once refused to recognize the value of a fact vital to the truth or falsity of a cause at issue because the concrete evidence of it was so small that it could only be seen by the microscope.

An unscrupulous pretender once informed a court and jury in my hearing that strong sulphuric acid having blackened a surface of paper with which it came in contact "the color afterwards faded."

It is not lawyers who are most responsible for degrading expert testimony on handwriting; they wish to win their cases and are frequently not quite so particular about the means as the members of the old bar are said to have been. But it is the Judges who are most to blame. Some of them from ignorance of the difference between scientific methods and quackery: others from a disbelief that any one can be entirely uninfluenced in his conclusion in a case affecting the man who pays his fee. These judges are themselves (presumably) chosen for their positions because they are experts in the law, and would visit condign punishment upon a plain citizen who accused them of soiling their judicial ermine by deciding cases in favor of the side best able to promote their advancement. Yet they not infrequently join in the hue and cry against other experts, and very particularly those in handwriting.

It is a fact that expertism in handwriting has been one of a

number of refuges of humbugs and perjurers for hire from the earliest times, and is so today, but even the bench is not entirely free from the same class. No efforts of handwriting experts as citizens could appreciably raise the standard of the Judges, but the latter might easily raise the standard of the handwriting experts by punishing those who are caught in flagrant crime, and more still by according respectful treatment, and protecting from wanton insult by bench and bar, those who have not forfeited the right to be held honest and competent.

The most superficial consideration of the subject will convince anyone that with the advancing complexity of civilization experts in Courts of Law must ever be more and more a necessity. The only alternative to their employment is for Court and jury to be informed on all subjects. This being impossible, and experts on handwriting being as necessary as any others, the wisest course to pursue is to weed out the ignorant and venal. After all, the injury any physical expert can do is slight compared to that which may be done by the lawyer experts, for the testimony of the former affects, usually, but a part of the case, and may be offset, whether true or not, by counter testimony and partisan cross-examination. But the expert lawyer, by his incompetency, may wreck the entire case of his client; and the expert Judge may do that, and make a vicious precedent besides to injuriously affect future cases; and the expert Supreme Judges may so offend the sense of justice of an outraged community that only a revolution with bloodshed can right the wrong.

The United States of America, unsurpassed in so many things, is unsurpassed in miscarriages of justice. There have always and everywhere existed some venal and unscrupulous individuals in every occupation, but events during the last few years hint at the possibility of the existence of organised expert perjury at the service of all malefactors, and, able to thwart justice by the most puerile and absurd contentions through an influence hard to comprehend. In connection with this bureau (if it be one) is a systematized subornation of misrepresentation and garbling at the very source of the syndicated news, so that in every morning paper from Maine to Georgia, and New York to San Francisco the daily story of some sensation which interests the people is distorted, every fact opposed to the conclusion the news-senders wish to attain being suppressed or perverted. To

any one with a particle of manliness, or a sense of fair play nothing can be more offensive than such misrepresentation of proceedings which he has, perhaps, himself witnessed.

The least of these frauds are gratuitous additions and comments such as "stammered the witness reddening to the ears;" or "the witness answered with some confusion;" or "with a guilty look of embarrassment."

Such phrases are introduced simply to prejudice the witness's standing before the reading public, and are generally wholly false.

The attempt has been sometimes made to raise the standard of an occupation degraded by abuses by applying to it scientific methods, and investing it with the character of a legitimate art such as the practice of medicine, or navigation. But the enthusiastic people who have tried such experiments have usually been rewarded as are the girls who marry drunkards to reform them.

M. L. Vallain, sworn-writer and expert in France, exclaimed "the verification of handwriting is within the province of the profession I have adopted, and I do not think it proper to refuse my aid to this kind of investigation, but I must add that I am far from seeking this kind of work."

And no wonder when so experienced and able a savant as M. Bertillon expended all his ingenuity and power in supporting the accusation of Dreyfus at the order of a then all-powerful faction in France. And not content with merely averring what his supporters wanted proven, he launched into the most extraordinary and imaginative hypothesis of a key word *"interet"* which he found pressed on a piece of blotting paper; and tried to prove by the calculation of probabilities that Dreyfus had forged (?) the bordereau, by means of a "gabarit" or key plan laid under the paper.

The Court of Cassation submitted this scheme to Darboux, permanent Secretary of the Academy of Sciences, Paris; Appell, Dean of the Faculty of Science, of Paris; and Poincaré, Professor of Mathematics of the same Faculty, who reported:

"That the system was without scientific value (1) because the calculus did not apply to the subject; (2) because the reconstitution of the bordereau was false; (3) because the rules of the

calculus of probabilities were not correctly followed. In a word the authors have reasoned badly on false documents."

If so scathing a report of the work done by the distinguished Bertillon can be made by men of the class of the signers of the report there is little hope of raising the tone of this study through the labors of those who exploit it merely for gain.

Yet when its province is recognized as within that of experimental psychology, entirely capable of being conducted like other investigations of the faculties of man, by exact measurement and numerical statement the shallow pretenders who have from time immemorial infested it will disappear.

PERSIFOR FRAZER.

Popular Science Lecture Series, Winter Course.

Delivered in Association Hall Y. M. C. A., Philadelphia, January 14, 1907.

GOLD AND SILVER PRODUCTION IN 1905.

Owing to the interruption of all normal business in the various parts of California, and particularly in San Francisco, caused by the earthquake that devastated that city last spring, the report of the United States Geological Survey on the production of gold and silver during 1905, has been unavoidably delayed. It is now, however, available and will be of interest to the whole mining world, as it contains not merely the statistics of production but minute and interesting data concerning the derivation of the gold and silver product from placers, from dry or silicious ores, copper ores, lead ores, zinc ores, copper-lead or copper-lead-zinc ores, and lead-zinc ores.

The author of the report is Mr. Arthur Lindgren. The figures showing the production of gold and silver, in approximate distribution by States and Territories, are the result of conference and adjustment between the Geological Survey and the Bureau of the Mint, and are accepted as final by two bureaus. The total production of gold was 4,265,742 fine ounces valued at $88,180,700; the total production of silver was 56,101,600 fine ounces valued at $34,221,976, making an entire total value of $122,402,676.

The production of gold in the United States for 1905 represented an increase of $7,716,000 in value over the production of 1904. The rapid advance in gold production which began in 1902, but temporarily halted from 1901 to 1903, was resumed in 1904. This increase in 1904 over the output of 1903 was approximately $7,000,000, and in all probability the increase in 1906 over 1905 will be at least the same amount. The chief sources of the great increase are as follows: Alaska added about $6,000,000 to its output of $9,160,458 in 1904, and Colorado, Nevada and Utah added about $1,000,000 each to their product of the previous year. On the other hand, decreases

are noted in Arizona, Idaho and other States. The States producing over $1,000,000 in gold rank at present in the following order: Colorado, California, Alaska, South Dakota, Nevada, Utah, Montana, Arizona, Oregon and Utah.

The production of silver in 1905 represented a decrease of 1,581,200 ounces in actual output, but in spite of this the increase in the average price 4 cents an ounce (from 57 cents in 1904 to 61 cents in 1905) effected an addition to the value in 1904 of $765,952. Two years of better prices for silver have thus far failed to stimulate the production. The record figures were attained in 1892, when the output was 63,500,000 fine ounces, valued at $55,662,500. A still further advance to the maximum of somewhat over 70 cents has taken place in 1906, but it is not likely that the year will show startling additions to the output for 1905. The increase should be more marked in 1907, and will probably be rather derived from copper ores and dry silver ores than from lead ores.

The decrease in the quantity of silver is specially noticeable in Colorado and Utah; to a slight degree also in Montana. On the other hand, Nevada and Idaho materially increased their output. The States producing over 1,000,000 ounces rank at present as follows: Montana, Colorado, Utah, Idaho, Nevada, Arizona and California.

The output of gold and silver in the United States is ascertained by the Geological Survey by the method of "Mines reports," that is, by direct inquiry from the producing mines. On the other hand, the Bureau of the Mint collects its data concerning the two metals by recording the quantities and sources of bullion deposits of the United States mint and assay offices, and by statements from the smelting and refining establishments detailing the quantities and sources of the metals produced. Statistics obtained by these different methods agree strikingly in the totals for the United States, but differ more or less in detail. Reasons for this are set forth in the report

The Government Irrigation Project at Roosevelt Dam, Salt River, Arizona.

By Prof. Oscar C. S. Carter.

Arizona has two well marked physiographic divisions; there is a high plateau comprising the northern half of the State which is from 4000 to 8000 feet above tide. The southern half of the State is a low desert area which, however, is mountainous in the eastern part. An escarpment or wall separates these two parts of the State. This escarpment enters from Utah on the north and trends from the northwest to the southeast; it is the southern border or edge of the Colorado Plateau, which is named after the Colorado River, which has cut a gorge for 200 miles through this plateau, which is from 4000 to 6500 feet in depth. This is known as the greatest scenic wonder in the world—the Grand Cañon of the Colorado River.

The high parts of this plateau in the north are more than a mile higher than the low desert in the south. It is this low country that is to be irrigated. It is out of the question to irrigate the high plateau country, because the Colorado flows through the Grand Cañon, which is so deep that the water could not be pumped from it and the prospects for artesian water on this high plateau are not encouraging.

The student of a quarter of a century or more ago had a very vague and erroneous idea of a desert, and if we examine the text-books of that time we will not wonder much at these strange conceptions of our childhood. A low and level expanse of sand, whirling in columns and drifting in heaps might describe limited areas of the African deserts but could have no reference to the deserts along the Mexican boundary line, the Yuma Desert, the Colorado Desert, Death Valley Desert, or the deserts of Nevada. Great mountain ranges with serrated crests gaunt and forbidding, enormous lava flows with rough and jagged surfaces. The great

variety of cacti with their beautiful but scentless flowers. Cacti which vary in height from the low egg-shaped forms but a couple of inches in height, capped with a yellow flower, which one sees on the Colorado Plateau, to the enormous cereus giganteus or suguarro of the Mexicans which rears its candelabra-like arms thirty and forty feet above the desert floor, reminding one of the flora of a past Geological Age. The sage, the Mexican greasewood, the mesquite, the occasional dense growth of chaparal took no part in the description of a desert in our childhood days. In an article on Death Valley by the author (see JOURNAL OF FRANKLIN INSTITUTE, Sept., 1902,) the reference is made to several interesting and valuable articles on the deserts of the United States. Notably, one by Captain Gaillard, of the Mexican Boundary Commission, on "The Perils and Wonders of a True Desert.' Another valuable and more recent article on the "American Desert," by Robert T. Hill, formerly Geologist of Texas. These articles give one a clear conception of our deserts as they are. Let one read the Report of the Mexican Boundary Commission, which is handsomely illustrated and is a valuable document especially from a geographic standpoint. It treats of a region most of which was practically unknown and new country before traversed by the engineers of the commission and which does not contain as many inhabitants as some of our rural towns. Some of the deserts along this boundary, like the Yuma and Colorado Deserts, are veritable Saharas and are even hotter and more arid. The Colorado Desert is named from the River of that name which flows through it and empties into the Gulf of California. This river could not exist in this region were it not fed by the snows and lakes of the Rockies, and yet these deserts bloom like a garden when irrigated; the soil is fertile, no plant growth has ever exhausted it; the only thing wanted is water, when it will produce five crops of alfalfa grass in a year. When the Government irrigation projects are finished the United States will take the lead as the foremost country in the world where irrigation is practiced on a gigantic scale. It must not be thought for one instant, however, that irrigation was not practiced extensively here before the Government Reclamation Service was esablished. Major J. W. Powell, formerly Director of the U. S. Geological Survey, in his statement before the Committee of Irrigation of the House of Representatives in 1890, stated: Mr.

Chairman, I have prepared a table by States and Territories of the land irrigated.

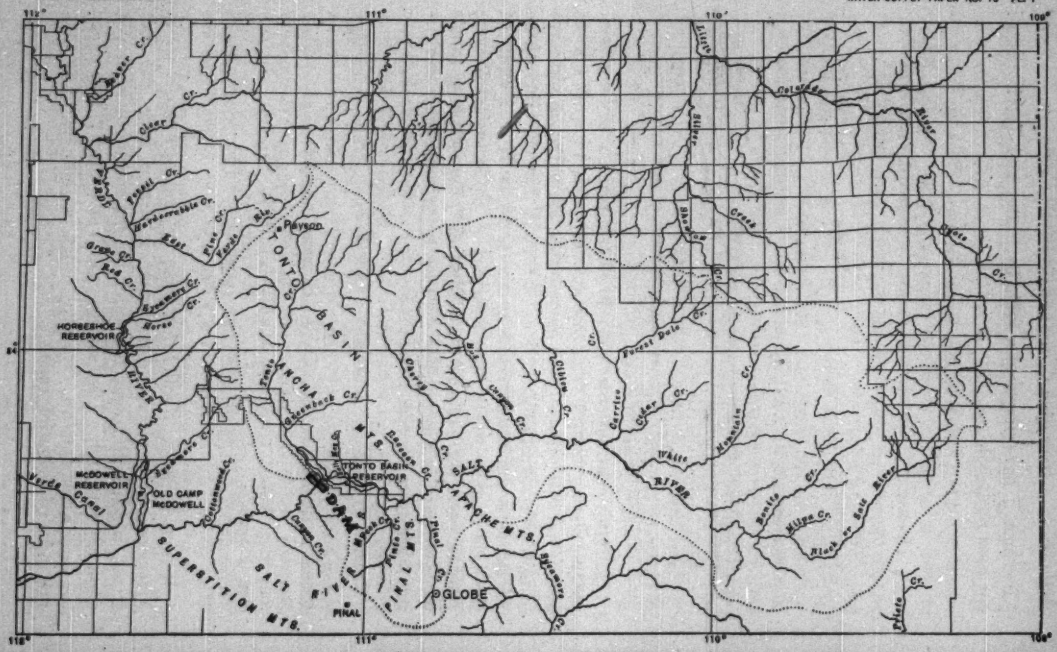
IRRIGATED AREAS TOTALS.

States.	Under ditches constructed or projected. Acres.	Irrigated and under ditch. Acres.
Arizona	455,600	175,000
California	6,000,000	3,000,000
Colorado		2,000,000
Idaho	740,000	400,000
Montana		348,000
Nevada		75,000
New Mexico	1,360,000	638,000
Oregon	191,000	119,000
Utah		802,000
Wyoming	1,227,819	500,000
Total		8,057,000

He states in a foot note, however, that the figures are not comparable among themselves as they are derived from many sources and by various persons, each having different purposes and ideas as to what constitutes irrigation. Mr. F. H. Newell, Chief of the Reclamation Surface States, in an article on the Hydrography of the Arid Regions (12th Annual Report U. S. Geological Survey, Part II, page 312,) that as far back as 1889 the following canals were reported in the Salt River Valley in Arizona, the water being taken from the Salt River:

Canals.	Length. Miles.	Canals.	Length. Miles.
Arizona	40	Utah	6
Grand	22	Farmers	5
Maricopa	14	Highland	22
Salt River Valley	18	Dutch Ditch	4
San Francisco	9	Monterey	4
Tempe	19	Griffin	3
Mesa	9		

It must be borne in mind that these 175 miles of canals are in Maricopa county alone and the water is drawn from the Salt River, which is to supply the water for the enormous Roosevelt dam, 285 feet high. The Gila River in Yuma county, into which the Salt River empties, furnished water in 1889 for more than 118 miles of irrigating canals.



DRAINAGE LINES OF SALT RIVER BASIN.

These figures show that irrigation was carried on extensively if not always scientifically before the Government took the matter in charge. The birth of the Government Reclamation Service marks a new dawn in the era of irrigation, because the highest engineering and scientific skill will be brought to bear upon these most stupendous projects which dwarf into insignificance by their immensity, former irrigation projects.

Major J. Wesley Powell was a remarkably well-informed man. After serving as Director of the U. S. Geological Survey for a number of years he was appointed Chief of the Bureau of Ethnology. It is an interesting fact that a number of the leaders of the Bureau of Ethnology to-day were formerly members of the U. S. Geological Survey. The present Chief, Mr Holmes, Dr. Fewkes and Mr Magee are among the leaders who were formerly geologists. There is little doubt but what their attention was first drawn to ethnology by their investigations in the West and their contact with the various Indian tribes and their familiarity with the various ruins and cliff dwellings. Powell was what might be termed a broad gauge man, while he had the knowledge of the specialist in many cases; his learning was rather of that broad and general character which gives one the power to correlate, classify and utilize scientific knowledge of many subjects. When he was testifying before the Committee on Irrigation of the House of Representatives he made some exceedingly interesting and valuable statements about the destruction of timber in the arid region which are ecrtainly worth repeating. Timber is an exceedingly important, though scarce, production in the arid region and for the Roosevelt dam across the Salt River more than 3,000,000 board feet, 800,000 feet of lumber, and about 1,100 poles have been cut from the Government Reserves on the Sierra Ancha Mountains, where a saw mill was erected, notwithstanding this will be a dam of solid masonry. Powell was asked by the Chairman about the rainfall on the mountains and in the valleys of the arid region. Powell explained to the committee that the rainfall is very irregularly distributed in the arid region. It is concentrated on the mountains and very little falls on the great valleys and plains. It is through the use of these mountain streams that 100,000,000 acres of land can be irrigated and redeemed, while the rain that falls on the valleys and plains sinks through soil and

sand and a great deal is lost by evaporation. He then placed a colored map before the committee which showed the forest areas in the arid region. This map was made from surveys carried on and was fairly accurate. These are of two kinds, first, the forests on high mountains and plateaus, which are the forests of commercial value, the pine, fir, spruce and sequoia. The area covered by forests of this class is not one-tenth of the whole; it is about 125,000 square miles, but all are on high mountains and plateaus and are not dense and could stand on one-fourth the space. In addition to these there are forests of some value covering a large area; these are pinion or nut pine, cedars and dwarf oaks. They are available for fire wood, fences and minor purposes. The area covered by these forests is a little over 130,000 square miles, so that within the arid region the extent of forest is about one-fifth and is scattered.

What Powell wanted to point out was the relation of these forests to agriculture and other industries of the country. The lower limit of the commercial forests varies from 4500 feet above the level of the sea at the north to about 6000 or 7000 feet above tide at the south, and from this lower limit the timber rises 4000 feet into the region above. Where these great commercial forests are, great snow falls occur during the winter and in the summer frosts may be expected, so that by reason of the altitude and temperature the region covered by these commercial forests is not fit for agriculture. The forests are being rapidly destroyed and it is of their protection and relation to agriculture that Powell spoke. The forests are utilized by the people who are engaged in agriculture in the valleys from five to one hundred miles away. They are burned as fire wood and utilized for mining purposes.

Mr. Herbert—"And the railroad companies also use them largely for cross-ties."

Major Powell—"Yes, sir; but ordinarily that is not a very great use. The mining use is great, the domestic use is very great, and the use for railroad purposes is of little importance. A man who cultivates a farm in this region usually has no timber on his tract. The timber with which he builds his house and fences and uses for fire wood grows many miles away. Hence they build roads into the cañon and bring the timber down, and they construct tramways and slides down the mountain sides and flumes, taking it out on streams of water and floating it down. So

that the timber region is always in another region from the farming industry. But the timber is being rapidly destroyed by fire.

U. S. Reclamation Service.

View showing the rank growth of cultivated flowers when watered frequently. Illustrating how an ordinary cottage can be beautified in Salt River Valley, Ariz.

That which man uses is insignificant. Man himself, taking the grand aggregate, has made no impression on the forests of that country. They grow faster than man has heretofore cut them

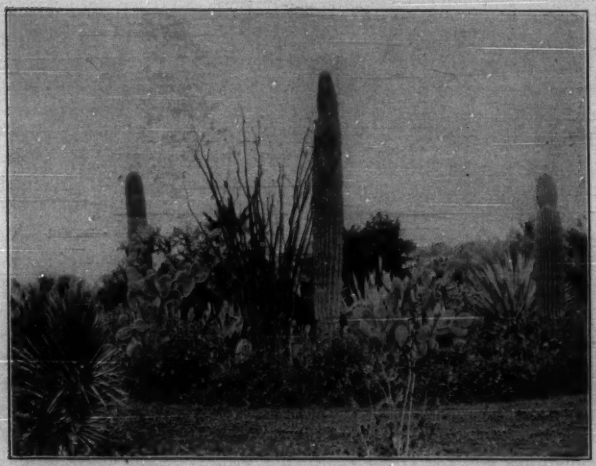
down, and if they could be protected from devastation by fire the use made by man would never injure the forests—not until a vastly denser population is gathered. These forests are composed of coniferous trees that are rich in inflammable resinous substances; the bark of trees is exceedingly inflammable and the pine needles that fall upon the ground are inflammable and all give rise to great fires and vast areas of forest have thus been destroyed. A little more than ten years ago I mapped the Territory of Utah and in making that map I delineated not only the existing forests, but the burned forests and found that at that time one-half of the forests of the Territory had been burned. I have seen one fire in Colorado destroy more timber than has been used by man from the migration to Pike's Peak up to the present time; and I have seen several such fires in Colorado. This past season, as an attaché to the Senatorial Committee investigating the question relating to the arid lands, I passed through South Dakota, North Dakota, Montana, Washington, Oregon and Idaho by train. Among the valleys, with mountains on every side, during all that trip a mountain was never seen. This was because the fires in the mountains created such a smoke that the whole country was enveloped by it and hidden from view. That has been the experience for twenty odd years, year by year, in this region. The geographical work of our Survey is cut off during the very dry months by the smoke; the men can not get lines of sight from height to height through that country because of the fires produced in the mountains and the smoke settling down over the land. In the last twenty years one-half of the timber has been burned. Where timber burns in this manner it springs up again; the lands as forest lands are not destroyed by these fires, but the timber itself is destroyed, and it is of slow growth."

Powell testified in 1890 and of course conditions are not now quite the same and the more recent careful surveys might change these estimates somewhat, but as late as the summer of 1905 while stageing a hundred miles through the heart of the Sierras the author saw forest fires that were doing great damage and even impeding travel.

Fifteen years ago there were very few irrigation engineers in this country. Irrigation engineering was just being recognized as a distinct branch and was engaging the attention of some of

the prominent engineers in the United States. The early stages in the development of irrigation had about passed and irrigation projects on a large scale were being considered and the construction of permanent and substantial works required a special personal knowledge which could best be gained by visiting a country where irrigation was conducted on a grand scale and where great engineering works of permanent value were constructed. Accordingly Mr. Herbert M. Wilson, C.E., was commissioned to visit British India and confine his observations to those features especially, which will be of greatest importance and benefit to

U. S. Reclamation Service.



View showing the different varieties of Cactus growth under cultivation at Insane Asylum near Phoenix, Arizona.

those who conduct irrigation on a large scale in the arid and semi-arid regions of the United States rather than to describe works of a novel and astonishing character. There is one rather curious and interesting statement made in the abstract of the Third Annual Report of U. S. Irrigation Survey, 1890-1891. Speaking of Mr. Wilson—"He shows the great benefits financially derived from the canals of India, and points out how in many localities the topography, climate and water supply re-

semble those of our arid West. Of course with our lower mountain ranges and smaller rivers, Americans cannot construct such great canals, nor are we called upon to build such gigantic structures for the control of water supply, but, on the other hand, the smaller irrigation systems of India serve as a means of comparison and enable us to draw conclusions as to the excellencies or defects of our own methods."

The above statement shows that fifteen years ago such irrigation projects as the Government engineers are working out and finishing to-day were never conceived or even dreamed of as being possible. Mr. Wilson said before his departure he was busily engaged in reading all the books and reports on Indian irrigation procurable, in order to plan the trip so as to see the most in the least space of time. Through the co-operation of the Director of the United States Geological Survey he left Washington in 1889 with a grip full of letters of introduction to various secretaries of public works, departments in India and to consular officers abroad and to prominent English engineers. He made a successful observation journey and examined only the principal canals navigable and non-navigable and neglected the deltaic and inundation canals, as he said there was little or no probability that such works will ever be constructed in the United States. He said: "India stands pre-eminent for her gigantic engineering undertakings. No other country has so vast and so fertile an expanse of territory, with such convenient slopes for the construction of canals, and at the same time such an abundant water supply. In general there is great similarity between the climate and topography of the great northern plains of India and portions of our arid West, especially the eastern slope of the Rocky Mountains and the Great California Valley. Central India and the Deccan have many features in common with the central arid Territories, particularly portions of Northern Arizona and Southern Utah. The climate is as similar to that of our central Territories as is the topography. The average annual precipitation rarely exceeds thirty inches, while the precipitation during the autumn crop varies between two and six inches. The topography of the upper Mutha Valley seemed very familiar. Had I been suddenly transported in my sleep to Northeastern Arizona the similarity of the topography of the two regions could not have more strikingly impressed me. At Lake Fife the Mutha

River makes its exit through a narrow cañon similar to those of the mesa country in Northern New Mexico and Arizona and the cliffs are similar in their abruptness and sharpness of outline to the mesa cliffs of our Southwest. Wherever the soil is uncultivated it is covered with a low scrubby grass dried and parched by the sun. At the canal edge the barren slopes are suddenly merged into endless green and well cultivated fields. The slopes of the hills are rocky and barren, covered with a growth of low trees among which babul or mesquite is the most prominent."

One recognizes in the above description a kind of topography

U. S. Reclamation Service.

Excellent pasture in Salt River Valley. The Result of Irrigation.

which is common in the arid Southwest, although the rainfall is much less with us. The Gila River is the principal stream in Southern Arizona. It empties into the Colorado River near the town of Yuma. Its principal tributary is the Salt River, which lies south of the center. The Upper Salt drains that portion of the territory east of the center. The largest tributary of the Salt River is the Verde which drains the central part of Arizona. The Salt River brings more water to the main trunk of the Gila

than the Gila carries before they join. This is due to the fact that the Salt River rises in the mountains, and the peaks from 10,000 to 11,000 feet are high enough to get a generous rainfall. The Salt River drains a mountainous country east of where the Verde joins it. There is another tributary east of this called the Tonto Creek. A half a mile below this stream the river enters a great cañon with precipitous walls and a narrow bottom. In this cañon is located the great Roosevelt dam of the Salt River.

Mr. A. P. Davis in Irrigation Paper 73 advances another reason why there is more rainfall southwest of the Colorado Plateau in Arizona than there is on the plateau—"Another partial explanation is found in the meteorological condition. The moisture of this region is brought from the Pacific Ocean and the Gulf of California by the prevailing southwest wind. As this wind ascends the elevations toward the Colorado Plateau its temperature is lowered which reduces its capacity for holding moisture and increases its relative humidity. When this quantity reaches 100 per cent. in any part, precipitation occurs. This influence continues until the wind passes the summit where the process is reversed. Therefore, the hydrographic resources of the country immediately southwest of the Colorado Plateau is disproportionately great when compared with those to the northward. For instance, the precipitation at Fort Apache, as shown by a mean of twenty years observations, is 19¾ inches, the elevation being 5,050 feet, while the precipitation at Holbrook, at an elevation of 5,047 feet, on the northern slope, is 8.47 inches, as indicated by a mean of ten years observations. This is an important fact especially when taken in connection with the fact that the great areas of valley land with a semi-tropic climate lie in the southwestern portion of the Territory, and are easily covered by the streams which are formed by the conditions above described, and which constitute the main features of the great Gila River system."

The following extracts, quotations and general information pertaining to the Roosevelt dam and its construction are taken from Irrigation Paper No. 73 by A. P. Davis: In the deep cañon where the dam is being built a great deal of silt had accumulated and borings to bed rock were made at thirty-one points in the cañon. In the upper end they found from 44 to 64 feet of river silt. The dam of course must be built on solid rock,

so more than a quarter of a mile farther down the cañon they found by boring a favorable site where the river silt was less than half the above amount. He says: "The gorge on Salt River is an especially favorable site for a masonry dam, and the most permanent, conservative and secure form of high dam that is known to engineering science can be constructed. The formation is sedimentary, with the strata inclined at an angle of about 30° to the horizon dipping toward the reservoir, a most favorable

Water Supply Paper 72.

Salt River Dam Site Looking Downstream.

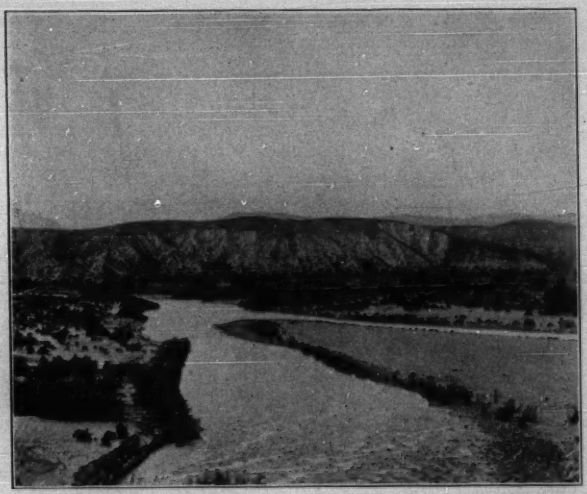
condition for retaining stored waters and for the stability of the dam. The foundation and abutment of hard, tough, fine grained sandstone are all that could be desired. Building stone of the same material is at hand above the site. Good Portland cement can be made in the vicinity. Sand for mortar can be obtained from the river bed, but will have to be washed and screened, and it is thought that the best plan will be to manufacture sand by crushing quartzite, which occurs in abundance near the site. This will provide an ideal sand, and as power is abundant its cost will

not be great. The dam must be so designed and constructed as to be safe from destruction by any or all of the forces acting upon it. It is possible for a masonry dam to fail in any one of three ways: 1. By overturning; 2, by sliding on the base, or on any horizontal joint; 3, by crushing its foundation or masonry near the base. A factor of safety of at least two is secured against overturning by so designing the dam that under all conditions the resultant of all the forces acting will fall within the middle third of any horizontal joint. This also eliminates the possibility of any tensile strains in the masonry, a very desirable result. The same condition also secures safety against sliding, which is insured in a still greater degree by constructing the masonry of random rubble, and by the use of hydraulic mortar, bonding it together and to its base, so that it becomes a true monolith—a part of the solid rock to which it is firmly joined. Under these conditions a large margin of safety is provided, as the structure cannot slide without shearing the masonry. In addition to these precautions the dam planned is to be built in the form of a circular arch, greatly increasing its safety against both sliding and overturning. In fact neither can occur without overcoming the gravity and cohesion of the masonry, and also crushing the masonry or abutments. The total factor of safety against failure by the first and second methods can not be exactly known, but it is unquestionably very great. The recorded failures of high masonry dams are as follows: At the Habra dam in Algiers poor hydraulic lime was used, and a red earth with a large percentage of clay was used in the mortar instead of sand. This combination made a poor mortar, and the rock was also poor, being a porous calcareous grit. It is supposed that the failure occurred by the crushing of the foundation under a computed stress of 13.3 tons per square foot. At the Bouzy dam in France the foundation was fissured and permeable and not on solid rock, allowing an immense upward hydrostatic pressure; the section was so light as to permit great tension in the masonry in the back. It was straight in plan, and when the reservoir was nearly filled the central portion of the wall was shoved forward about a foot, causing ruptures and leakage. This was afterwards repaired and the foundation reinforced. Six years later when the reservoir was full the dam suddenly overturned at a plane about 33 feet below the top. The above recited defects were the un-

doubted cause. At the Puentes dam in Spain the central portion of the dam was founded upon piles driven in earth. When the rising water applied a heavy hydrostatic pressure, this portion of the foundation suddenly gave way and left the top and ends of the dam standing in the form of an arched bridge.

"The dam at Austin, Texas, was an overflow dam built of limestone rubble, the stone being very soft and of poor quality. The foundation was on a geological fault and was of soft lime-

Water Supply Paper 73



Salt River Reservoir Site Looking Upstream.

stone, in thin horizontal layers, which had little adhesion and probably very little friction upon one another, and the failure, which was by sliding, is supposed to be due to this fact.

"In all four of the above cases the foundation was defective. In three the stone was poor and in two the mortar was poor. All were straight in plan except the Puentes, which was polygonal in plan and arched up stream. This dam seems to have been very well planned and constructed except for one fatal defect of being founded on piles instead of solid rock. All of the defects in

these failures can easily be avoided in the proposed dam by a reasonable application of care and skill. The proposed dam is designed to be 217 feet above low water in the river at the dam site and to store water at a maximum depth of 190 feet. The total height of the dam above lowest foundation will be about 247 feet."

Since Mr. Davis' report was written the dimensions of the Roosevelt dam have been increased (see 4th Annual Report Reclamation Service.)

Length of dam at datum	210 feet
Height of spillway above mean low water	220 feet
Height of roadway above mean low water	240 feet
Total height of dam from foundation to parapet	285 feet

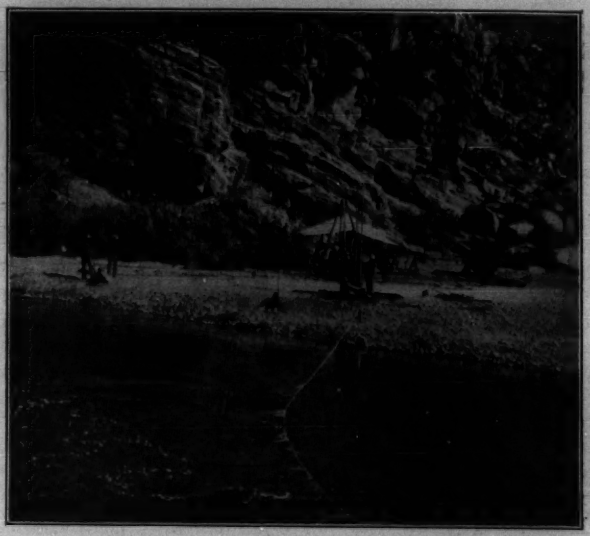
This dam will back the water up Salt River about 16 miles and up the Tonto Creek nearly as far. It will produce a lake over 25 miles long and from one to two miles wide The reservoir will have a capacity greater than that of any other artificial reservoir in the world.

Spillways 20 feet deep will be excavated in the solid rock sides of the cañon and the rock used in the construction of the dam.

The location lends itself admirably to a curved form of dam, this form containing but little more material than a straight one of the same section. The proposed structure is to be built on a circular curve, convex up stream, the back having a radius of 400 feet and the face a shorter radius from the same center The dam is to be of uncoursed rubble masonry and to have a section on modern conservative ideas as a simple gravity structure, and the added stability due to its curved form will greatly increase its factor of safety. The rock of which the dam will be constructed will be excavated from the spillways and is a tough, close-grained sandstone. Two cubes with edges of two inches were cut from samples of the rock to be used in Salt River dam and crushed in the testing machine at the United States Navy Yard at Washington. Sample No 1 crushed at 59,650 pounds, being 14,912 pounds per square inch or 1,074 tons per square foot. Sample No. 2 crushed at 100,000 pounds, this being 1,800 tons per square foot. These results are so high that the strength of the rock is entirely eliminated from the discussion. The rock is to be used in as large pieces as practicable, in order to make the number of

joints as few and the quantity of mortar as small as may be. It is estimated that rock will occupy 70 per cent. of the structure. Fifteen per cent. will consist of cement mortar in which the stones are bedded and fifteen per cent. will consist of cement concrete rammed into vertical joints. Taking the weight of the mortar as 115 pounds per cubic foot and that of the concrete as 130 pounds, the masonry will weigh as nearly as can be estimated 146

Water Supply Paper 73



Drilling party on Salt River. Line A of Borings.

pounds per cubic foot. On this estimate the strains have been computed and the section of the dam designed. As the dam is to serve as a highway, a top width of sixteen feet has been adopted with parapets along the sides. The pressure on the top when the reservoir is full will be 15.9 tons per square foot, computed on the assumption that the dam is a rigid-monolith and non-elastic.

Specifications in Brief for the Construction of the Dam.

Diversion of the River.—The diversion of the river will be accomplished by means of sheet piling driven as deeply as practicable directly across the cañon, beginning at south side and reaching as nearly as practicable to bed rock, the piling to be reenforced at and above the surface by a heavy wall of sand and gravel excavated from the site of the dam, the water to be diverted through the outlet tunnel which will be constructed in advance.

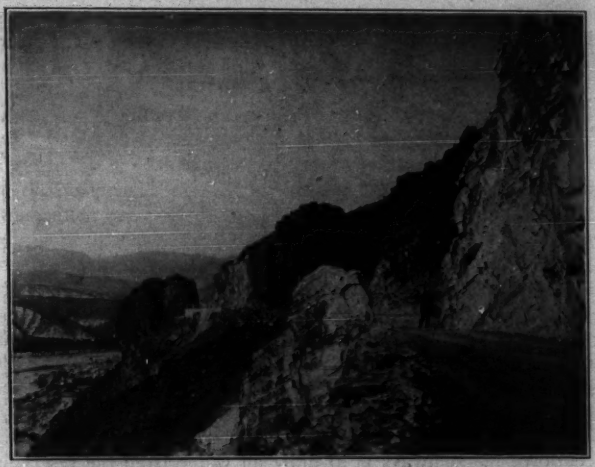
Foundation.—All earth, sand, gravel and boulders, disintegrated loose and seamed rock will be excavated and removed from the entire area of the base of the dam in order to secure a firm foundation on solid rock. Explosives shall not be used in excavating the rock unless absolutely necessary, and then only in small quantities in shallow holes to avoid fracture of the rock forming the foundation of the dam.

Masonry.—The main body of the dam shall be constructed of broken range cyclopean rubble. The stone shall be quarried from the walls on each side of the cañon. If sufficient quantity of hard fine grained stone cannot be obtained in these spillways it shall be quarried elsewhere. All stone shall be washed and laid in Portland cement mortar. No mortar joint in the face shall exceed one inch in thickness. The body of the dam shall be composed of as large stone as practicable, well shaped and laid so as to break joints and bond in all directions. Vertical joints between the stones must be nowhere less than four inches and must be filled and rammed with Portland cement concrete. The aim shall be to use the largest proportion of stone and the smallest proportion of mortar and concrete. Facilities shall be provided for handling stones weighing twelve tons, and large stones shall be used as far as practicable.

Mortar and Concrete.—All mortar used in the lower thirty feet of the dam shall consist of 1 part of Portland cement, 2 parts of good sharp sand; and all concrete used in this portion of the dam shall consist of 1 part cement, 2 parts sand and 3 parts of broken stone as will pass through a screen with meshes 2 inches square. The mortar and concrete used in the upstream face of the dam for a thickness of 20 feet shall be of the quality above specified. In all parts of the dam which are more than 20 feet from the up-

stream face and 30 feet from the base the mortar shall be 1 part Portland cement, 3 parts sand, and the concrete one part Portland cement, 3 parts sand and 4 parts broken stone of a size to pass through a screen with meshes 2 inches square. All mortar and concrete shall be thoroughly mixed and used so promptly that there will be no danger whatever of incipient setting of the cement previous to the completion of the masonry in which it is placed. No cement shall be used until at least sixty days after its manufacture and not until it shall show satisfactory tests according to chemical and physical requirements adopted by the Ameri-

U. S. Reclamation Service.



Government Road Salt River Project Ariz. Just over Roosevelt Dam site.

can Society of Civil Engineers. The reason for using a larger percentage of cement in the base of the dam is that here will be the greatest pressure, and the higher percentage of cement will give a greater power of resistance to crushing. The higher percentage of cement is maintained on the water face of the dam all the way to the top in order to render it as nearly impervious as possible. It may be confidently predicted that a masonry dam at the proposed site, constructed on the above plans and specifica-

tions, would be absolutely permanent, safe, solid, and secure for all ages to come, as truly as the everlasting hills, of which it will become an integral part."

SEDIMENT.

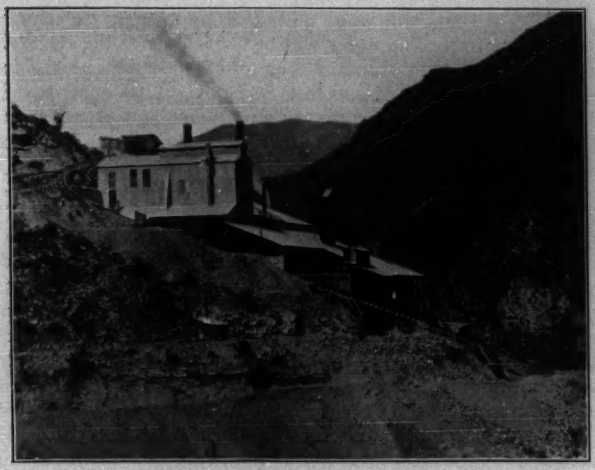
Mr. Davis also states that "most of the streams of the Southwest carry considerable solid matter which causes annoyance in canals and has a tendency to fill any reservoir constructed on the stream. This is true of the Rio Grande, Colorado, Pecos, and Gila Rivers. There is silt also in the waters of the Salt River as shown by its occurrence in the canals, but it is not nearly as abundant as in the streams above mentioned. The basin tributary to the Salt River reservoir lies in large part in high timbered country and includes the Apache Indian Reservation. The reservation is almost entirely covered with forest and grass. The Tonto Creek and a few other tributaries deliver some silt during floods. From observations of the amount of sediment carried he found the amount so small as to be almost negligible, but the discharge during the year was far below the normal. It would probably be 100 years before the loss of storage capacity would be seriously felt and it would be necessary to resort to methods of clearing it out. The greatest amount of sediment will usually be found in the lower layers of water and it will therefore contribute to the maintenance of the storage capacity to drain all the waters from the lowest possible point at all times. Two outlets are provided in the form of tunnels 10 by 13 feet, one around each end of the dam. Whenever water begins to run over the spillway the gates must be opened to full capacity not only to draw off the maximum quantity of sediment but to reinforce the spillway. The plan adopted then to facilitate the discharge of sediment and reinforce the spillways is to draw all water from the reservoir through large openings directly on the bottom. The two tunnels will be dug through the solid rock, one on each side of the cañon."

POWER PLANT.

He further says: "In the construction of a great dam one of the most important elements is that of power. This is necessary on a large scale for drilling purposes, for handling rock, for mixing and handling mortar and for crushing rock to be used in concrete. In the present case it has been found possible and very de-

sirable to manufacture on the ground the large quantity of cement required in the dam. This would require about 300 horse-power day and night for grinding rock and clinker and for handling materials and running machinery. It is usual to provide such power by means of steam engines, but in the present case this is rendered very expensive by the scarcity of fuel. Coal in quantities, now costs $10 per ton in Globe, and the wagon haul to the dam site would nearly double this. A limited amount of

U. S. Reclamation Service.



Detailed view of the Cement Works, Roosevelt Dam.

wood is available, but to secure the large quantity which would be required if it were the sole dependence for power would involve a long haul. The best means for providing the necessary power is by the development of water power on the river. This will involve the construction of a diversion dam and canal, which can afterwards be utilized if required for sluicing accumulated silt out of the reservoir. The power developed can be used in the neighboring mines or in the valley below for pumping purposes. The proposed canal would head some distance above the reser-

voir, follow above its water line, and finally discharge just below the dam, with an available head of about 180 feet. It is designed to deliver 100 cubic feet per second, and to develop a net energy of about 1200 horse-power after deducting seepage, friction, and the losses in water wheels, electric plant, etc. It is designed to use 900 horse-power at the dam and 300 horse-power at the cement mill. The power plant will consist of three units of 300 kilowatts each."

Since Mr. Davis' report changes were necessarily made in the canal and power plant (see 4th Annual Report Reclamation Service.) The canal will be 19 miles long and have a capacity of 200 second feet. The water will be carried above the reservoir to a point below the dam and there discharged through turbine wheels under a head of 220 feet, developing 4400 horse-power, to be used in constructing the dam and pumping water for irrigation in Salt River Valley. The water wheels and dynamos were increased.

CEMENT MANUFACTURE.

The problem of furnishing cement at a reasonable expense was an extremely serious one. It is an isolated locality and there is a wagon haul of 40 miles over exceedingly rough and mountainous country to the nearest railroad, which is a branch road with light traffic and high rates. It was estimated that cement would cost at the dam about $9 per barrel, and as later calculations showed that at least 220,000 barrels of cement would be required in the construction, the total cost was prohibitive. It was finally decided to make a careful search in the vicinity for the rocks out of which cement is made, namely—limestone, clay or shale, and if found in abundance and right composition for the manufacture of cement then a cement plant could be erected and the problem solved. With this end in view search was made in the Tonto basin for limestone, clay and shale. Eight samples in all were sent in for analysis to the superintendent of the cement works at Colton, California. Samples 1 and 7 seemed to be the most satisfactory. No. 1 was a limestone near the dam site, very abundant and convenient. The analysis showed:

Alumina and ferric oxide	0.20
Magnesia	.60

Calcium carbonate	95.80
Insoluble residue	3.30
	99.90

No. 7 was a clay from the hills 3 miles north of the dam site, very abundant. The analysis of the clay showed:

Moisture	13.40
Silica	51.90
Alumina and ferric oxide	23.70
Magnesia	.97
Calcium carbonate	10.90
	100.87

The shales that they found were expensive to quarry and grind, so they were discarded as they would only have been used if no suitable clays were found. All shales were once mud or clay laid down in ancient seas or lakes, and when the water disappeared pressure consolidated the mud or clay into shale. Samples of the limestone and clay were sent to Mr. E. A. Duryee, superintendent of the cement works, for an experimental burn. He reported as follows: "The clay and limestone were ground separately and then mixed in the proportions of 6.18 pounds of limestone and 2.25 pounds of clay, making a raw mixture that tested 43 per cent. lime. As the limestone was very hard and therefore more difficult to make into cement than a softer material, fluor spar to the amount of 1½ ounces or 1 per cent. was added. The materials were also ground quite fine, but no finer than is the practice in some cement works. The raw mixture was made into briquets and these after being dried were burned in a gasoline furnace. They burned to a good hard clinker of a good color.

ANALYSIS OF CEMENT.

Lime	63.56
Alumina and ferric oxide	10.40
Silica	22.85
Magnesia	.71

Alkalies not determined.

TENSILE STRENGTH OF NEAT CEMENT BRIQUETS.

	lbs. per sq. inch
7 days (1 day in air, 6 in water)	410
14 days (1 day in air, then in water until broken)	690
28 days (1 day in air, then in water until broken)	775

These results proved that an excellent quality of cement could be made on the ground. Mr. A. P. Davis states: "The greatest difficulty is the scarcity of fuel. There is considerable wood in the reservoir site, mainly cottonwood and mesquite, which it will be desirable to clear out of the reservoir in any event. Wood is not suitable for burning cement clinker by modern methods, but if made into charcoal and then ground to powder would answer, or oil may be imported for the purpose from California. A large amount of power is required for grinding the rock and the clinker and a still larger amount will be necessary in the construction of the dam, for excavating to foundation, quarrying and handling the rock, mixing and handling the mortar, etc. If steam power were used for all these purposes the small amount of wood at hand would soon be exhausted and it would be necessary to haul wood a long distance or to import coal, either of which would be very expensive. Water power can be developed by diverting water from Salt River above the reservoir site, carrying it in a canal above the proposed lake and dropping it through a penstock just below the dam. By such means an ample supply of power can be obtained, available through the construction period and afterwards also if desired."

"The estimated cost of the cement plant, with modern machinery, capable of producing 300 barrels per day, as furnished by Mr. E. A. Duryee, is $91,000. With such a mill using charcoal for burning cement the cost of manufacture would be approximately $2 per barrel. It was finally determined to burn the cement with crude California petroleum. Eleven gallons are required to burn a barrel of cement. The contract price was $3.48 per barrel, delivered at the cement mill in quantities of 3000 barrels monthly. The oil is hauled by rail from California to Mesa, Arizona, thence by traction engine 24 miles and by mule teams 37 miles to Roosevelt. (See 4th Report Reclamation Service.) The road from Globe to Payson passes through the reservoir almost its entire length. In case of the construction of the dam this road would be submerged and it will be necessary to provide a new one around the reservoir. If it were deflected to the east it would be thrown into an exceedingly rough mountain country, where the construction would be very expensive and the road beset by heavy grades. By passing to the west of the reservoir it would be necessary to use the dam as a viaduct and to

build bridges across the spillways. There would not be a great amount of road constructed and this plan would be far cheaper and furnish a much better road than could be built east of the reservoir."

Twenty miles of road were afterward built to connect Globe with the dam site. Altogether it has been necessary to construct 110 miles of road, part of which replace roads that will be flooded by the reservoir.

In January, 1906, the Reclamation Service issued the following statement for the public:

ARIZONA: SALT RIVER PROJECT.

This project contemplates the construction of a large storage dam at Roosevelt, Ariz., 270 feet in height, which will regulate the supply of water from gravity systems for about 160,000 acres of land in the vicinity of Phœnix. When the dam is constructed there will be developed a large amount of power which will be utilized to increase the water supply in the Salt River Valley by means of pumping from underground sources. Early in 1904 contracts were awarded for the construction of considerable auxiliary work, power canals, sluicing tunnels, etc. A cement mill was erected by the Government and is now in operation, furnishing a first-class quality of cement to be used in the works. The construction of the dam will require 220,000 barrels of cement. The excavation for the power canals is completed, the lining of canals is nearly completed, and the work on the sluicing tunnel was finished Oct. 3rd, 1905. The contract for the construction of the large dam was awarded to J. M. O'Rourke & Co., of Galveston, Texas. It is understood that there are no public lands available under this project for homestead entry, the entire area having been filed upon by settlers, many of whom have gained title to the land. For information as to the possibility of acquiring lands by purchase from present owners, and other data of a local character concerning the soil and climate of the valley, apply to Mr. B. A. Fowler, President of the Salt River Valley Water Users' Association, Phœnix, Ariz. The irrigable lands under this project are tributary to branch lines of the Southern Pacific and Santa Fe Railroad systems.

ROCK ANALYSIS.

"The analyses of Silicate and Carbonate Rocks" is the title of a forthcoming bulletin (No 305) of the United States Geological Survey, which will be of interest to chemists and geologists. The author is Dr. W. F. Hillebrand, who collaborated in 1897 with Prof. F. W. Clarke in the preparation of a bulletin (No. 148) on the analyses of rocks, in which a chapter was devoted to a description of the analytical methods in use in the laboratory of the Survey. This bulletin was so favorably received by chemists that it was found advisable to republish in 1900 a portion of it in more extended form as Bulletin No 176. This was credited to Dr. Hillebrand and bore the title of "Some Principles and Methods of Rock Analysis." Since then two other treatises on rock analysis have appeared: "Manual of the Chemical Analysis of Rocks," by Dr. H. S. Washington (1904), and "Anleitung zur Gesteins-analyse, by Dr. Max Dittrich (1905). The former is based largely on Bulletin No. 176; the latter, while adopting some of the methods advocated in that bulletin, adheres more to methods which are in greater favor in Germany than in this country. They both differ from Bulletin No. 176 in devoting less space to a discussion of principles and to a determination of the less common constituents of rocks. They have not, therefore, rendered the Survey publication superfluous. On the contrary, since some methods have undergone improvement or been superseded by better ones, the time seems ripe for its republication in revised form.

The literature relating to analysis of silicates is extensive but scattered. Up to the time of the Survey's publication of Bulletin No. 148, no satisfactory exposition of the procedures to be followed or the precautions to be observed in analyzing silicates was in existence. The need of such guidance was especially felt in the search for some of the rarer constituents, or those which, without being rare, have been of late years recognized as occurring persistenly in small amounts. As the outlines of some methods and procedures set forth in those earlier bulletins seem to have been too meager for the use of students, many of them have received considerable elaboration in this last edition.

For the reason that the chief carbonate rocks form so important an element in the composition of the earth's crust, and the knowledge of their composition is of moment to the geologist as well as to the cement maker, who now makes enormous use of them, a special section devoted to their analysis has been added. The methods applied to their analysis differ in but unimportant respects from those used with the more siliceous rocks, since they are to a great extent themselves siliceous, contain essentially the same constituents, and therefore the same principles apply to both.

Special problems relating to the analysis of rocks of extra-terrestrial origin—the more or less strong meteorites—are not considered in this treatise.

Section of Physics and Chemistry.

Some Well Known Synthetic Chemicals and Their Relation to the Pure Food and Drug Act.

By Lyman F. Kebler.

Chief Drug Laboratory, Washington, D.C.

The word "synthetic" as used in the chemical world, means a combination of separate substances, elements, or radicals, which results in the formation of definite chemicals. The manufacture of acetanilide from benzol, or antipyrine from aniline afford good illustrations, inasmuch as in the manufacture of both several operations are necessary. The word "synthetic," however, has acquired an entirely different meaning which has been used to a considerable extent in the past, usually in an honorable manner, but often for the purpose of deceiving not only the public, but also the doctor as well. This feature has been claiming recognition in no unmistakable terms during the past few months. It is held by some that the mixing together of the various cinchona alkaloidal salts, in proportion as found by analysis of the cinchona barks, the same dissolved in simple elixir and colored with caramel, is a "synthetic elixir of cinchona bark." Other illustrations are the common headache mixtures which consisted in the past, and at present to a lesser extent, chiefly of acetanilide, sodium bicarbonate, or ammonium carbonate, and caffeine. These mixtures are at times so named as to lead to the belief that they are synthetic chemicals. In some cases a hypothetical chemical name, together with a structural formula, are attached to make the deception even more complete. Since the passage of the act, the acetanilide has been replaced in many instances by para acetphenetidin (commonly known as phenacetine) and antipyrine. This sub-

ject will be considered in a subsequent portion of this paper. It is also claimed that a so-called "raspberry extract" made up with various esters, dissolved in alcohol (grain or wood) colored with cudbear is a "synthetic raspberry extract." There are undoubtedly different views as to whether or not the latter claims are justifiable, but in the speaker's opinion, the first definition, or a similar one, is the only one that should receive any recognition in the chemical world. As a matter of fact, the latter is simply used to attract the attention of the public and has no basis for existence whatever.

The Pure Food and Drugs Act specifies that an article is misbranded if it fails to bear a statement on the label of the package "of the quantity or proportion of any alcohol, morphine, opium, cocaine, heroin, alpha or beta eucaine, chloroform, cannabis indica, chloral hydrate, or acetanilide, or any derivative or preparation of any such substances contained therein." The act also forbids the use of any poisons or deleterious ingredient in the manufacture of food products, or any agent which misleads or deceives in any particular. The two phases of the act just considered require, first, that the presence of certain habit forming drugs, shall be declared on the label, and second, no injurious agent, or agents, which deceive in any particular, shall be used in the manufacture of food products.

It can readily be seen by chemists familiar with the ingredients enumerated in the act that the phrase "derivative and preparation of same" is very comprehensive, which was undoubtedly the intention of Congress. This clause was undoubtedly introduced for the purpose of preventing or evading prosecutions under the law on pure technicalities. For example, it has been held by the defendant in a number of cases where a prosecution was brought, on the ground that a product contained the forbidden ingredient, morphine, that the ingredient present in the product under consideration, was not morphine, but morphine sulphate. The same position has been taken in other cases, for example, it is contended by some manufacturers that the introduction of cocaine through the medium of an extract of coca leaves, or by extracting coca leaves directly with the menstruum of the article, cannot be considered a cocaine preparation any more than could coffee be construed as a caffeine product. It is immaterial

how cocaine is introduced into a product; the fact of its presence renders such a product a cocaine preparation. Any other conclusion must be based on a technicality or is a mere quibble.

So far as the word "preparation" is concerned, as used in the act, there does not appear to be any question relative to its meaning, but this is not the case with the word "derivative." The term "derived from" as used in the tariff law of 1897, has not only been subject to decisions at the hands of the appraiser of the United States Customs Service, but has also been defined by the United States Federal Court (1899 Federal Reporter 719) and the United States Court of Appeals (102 Federal Reporter 603). The decisions arrived at are that the words "derive," "derivation," "derivative" must be interpreted as "made of," "prepared from," "produced from," "obtained from," and that the term "derived from" has its ordinary meaning of "produced from" and relates to the physical substance from which such product is obtained and *not to its chemical relationship*. In other words, if the manufacturer starts with alizarine and by partial replacement produces a dye, such dye is derived from alizarine, but not otherwise. The question under consideration in the above decisions was whether or not certain dyes were derived from alizarine. These precedents must undoubtedly be taken into consideration in connection with the recently enacted pure food and drug law, but the aims and objects of the latter are entirely different from those of the tariff law.

The meaning of the term "derivative," as used in the act, has been called into question because (para) acetphenetidin is classed as a derivative of acetanilide. There is no question but that (para) acetphenetidine is a derivative of acetanilide, both chemically and physiologically and resembles it in its tendency to habit formation, physiological action, and physical properties. Furthermore, Treasury dicision 13270 construes this chemical as an alcoholic medicinal preparation. The exact status of this product under the law therefore appears to be in a somewhat unsettled condition at present.

In this paper only a few of the synthetic chemicals that are affected by the Federal Law, will be considered. For the purpose of ready reference, it is deemed desirable to collect them into the following groups:

	Common names.	Synonyms and Chemical names.
1st. Alcohol Group.	Ether	Sulphuric ether, Ethyl ether.
	Ethyl acetate	Acetic ether.
	Ethyl nitrite	
	Ethyl bromide	Monobromethane.
2d. Chloroform and hydrate Group.	Chloroform	Trichlormethane.
	Chloral hydrate	Trichlorethidene glycol.
	Chlorotone	Aneson; Acetone chloroform; Trichlorpseudobutylalcohol.
	Chloral alcoholate	Trichlorethidene ethyl alcoholate.
3rd. Cocaine Group.	Alpha Eucaine	Benzoyl-methyl-tetra-methyl-gamma-oxy-piperidin-carboxylic-methyl ester.
	Beta Eucaine	Benzoyl-vinyl-diacetonalkamin hydrochloride.
4th. Opium-Morphine Group.	Heroin	Diacetyl morphine.
	Dionine	Ethyl morphine hydrochloride.
	Peronine	Benzyl morphine hydrochloride.
	Codeine	Methyl morphine.
5th. Acetanilide Group.	Acetanilide	Phenylacetamide; Antifebrine.
	Phenacetine	Para-acet-phenetidin; Acetphenetidin; Para-acet-amido-phenetol; Para-oxyethyl-acetanilide.
	Antipyrine	Analgesin; Anodynine; Parodyn; Phenazon; Phenyl-dimethyl-pyrazolon Pyrazine.
6th. Preservative, Sweetening and Flavoring Group.	Salicylic acid	Ortho-oxy-benzoic acid.
	Benzoic acid	
	Vanillin	Methyl-protocatechuic aldehyde.
	Saccharin	Benzosulphinide.

In the above groups it will be noticed that not only are the common name employed, but also the synonyms and structural formula names. The object of giving the latter, is simply to call attention to the fact that manufacturers are making frequent requests to be permitted to use some other words than those specifically enumerated in the act, for example, one manufacturer represents that a setting forth on the label of the fact that his

product contains opium, would be a financial loss and asks whether it would not be satisfactory to state on the label that this product contains a certain amount of Papaver somniferum. Other manufacturers request that they be permitted to use the word phenylacetamide, or the phrase "the monacetyl derivative of aniline," or the structural formula in place of the word acetanilide. If it were permitted to use other words than those given in the act for the ingredients specifically covered, there would soon be such a confusion of names and structural formula that it would be necessary to consult an expert organic chemist to decipher same.

It is held by some writers that it was absolutely unwarranted to include some of the chemicals and products enumerated in the rules and regulations, because, in many cases such articles are never used as habit producing drugs. In this connection it should be stated that this question was submitted to about twelve of the best pharmaceutical chemists, manufacturing and analytical, and while a few think that the public would be protected just as well without requiring a declaration on the label of the presence of certain ones, yet on the whole every one heard from thus far suggested additional products to be included. In other words the suggestions of these men indicate that instead of having included too many drugs, the list should be augmented. Our general correspondence confirms this attitude. It should furthermore be noted that it seems necessary to include certain chemicals in order to avoid technicalities; for example, it is held by one chemist that a certain chemical could not be considered a derivative of alcohol, because ethyl bromide is not enumerated as a derivative of alcohol in the regulations, and inasmuch as this chemical is employed directly in introducing the ethyl group into the product, it is necessary that this product be included as a derivative of alcohol. The contention that certain ingredients are not used as habit producing drugs, is not well taken. This claim is made for ether, which, as a matter of fact, however, is used to fortify beverages in order to render intoxication more rapid and complete, particularly is this the case where parties are addicted to the alcohol habit and the ordinary beverage does not appear to satisfy the appetite of the consumer.

The morphine group presents some interesting features. It is well known that both morphine and opium, and the disastrous re-

sults of same, have been widely exploited during the past few years, not only in the lay journals, but also to some extent in the public press. Many manufacturers deem it expedient to remove these words from their labels if possible because of this unfavorable notoriety. The result is that these ingredients have, in many instances, been replaced with other products which are not so well known to the public, for example, heroin, codeine and dionine have replaced morphine in a considerable number of cases. These chemicals are at present supposed not to produce as deleterious results on the human system as do opium and morphine even when used over extended periods, but what the future will bring forth by their promiscuous and indiscriminate use, is difficult at present even to conejcture. It is even now reported that where narcotic laws prohibit the indiscriminate sale of morphine and no restrictions whatever are placed upon the sale of codeine, that the latter product is being used in place of the former.

What has been said above in connection with the opium-morphine group applies equally to the acetanilide group. At the time the pure food and drugs act was passed there were approximately 500 headache and laxative preparations sold through the jobbing trade under various names which contained acetanilide. It is a significant fact that the acetanilide in many of these preparations has been replaced by acetphenetidin (phenacetine), and we are also informed, from various sections of the country, that antipyrine is being employed for the same purpose. Exactly why some of these changes have been made, is not clearly apparent, because none of the substitutes are as cheap as the acetanilide, although the price of each has been materially reduced within the past few years. This is due largely to the fact that the patents covering these chemicals have lapsed, and the price has fallen in the case of acetphenetidin (phenacetine) from $16.00 to $1.00 per pound, and antipyrine from about $22.00 to $2.40 per pound, both in bulk. The price of acetanilide in quantity at this writing is 25 cents per pound. Another probable reason for replacing acetanilide by acetphenetidin is because the latter is supposed to have a less deleterious effect upon the human system than the former, but this is at present an open question. No one has thus far ventured to give this as an excuse for using antipyrine, because it is a well known fact that the latter is the most

dangerous of these three medicinal agents. Two other potent factors, however, should be considered in this connection. These are: (first), that the deleterious effects of neither acetphenetidin nor antipyrine have been given any publicity and the public therefore has little knowledge of the meaning of the words acetphenetidin and antipyrine, should their presence be declared upon the label; (second), it was expected that both of these chemicals could be used indiscriminately in medicines without the necessity of declaring their presence upon the label. Acetphenetidin, however, according to the rules and regulations made under the pure food and drugs act, must be set forth on the label.

The use of harmful preservatives in food products is forbidden. The exact status, of the harmful nature, of certain preservatives is at present not definitely settled. Among the most conspicuous preservatives used during recent years are the synthetic chemicals known as salicylic acid and benzoic acid and their salts. The experimental results obtained in the Bureau of Chemistry in connection with salicylic acid and the salicylates have just been published in Bulletin 84, part 2, from which part of the general conclusions are herewith quoted:

> "There has been a general consensus of opinion among scientific men, including the medical profession, that salicylic acid and its compounds are very harmful, and the prejudice against this particular form of preservative is perhaps greater than against any other material used for preserving foods. This is due not only to the belief in the injurious character of salicylic acid but perhaps is especially due to the fact that it has in the past been so generally used as an antiseptic. That salicylic acid should be singled out especially for condemnation among preservatives does not seem to be justified by the data which are presented and discussed in this bulletin. That it is a harmful substance seems to be well established by the data taken as a whole, but it appears to be a harmful substance of less virulence than has been generally supposed. The addition of salicylic acid and salicylates to foods is therefore a process which is reprehensible in every respect, and leads to injury to the consumer, which, though in many cases not easily measured, must finally be productive of great harm."

Benzoic acid and the benzoates are by many considered less harmful than the salicylates. Whether or not this is correct remains to be established by future experiments and observations. This much, however, is certain that whenever it is possible, and

usually it is, food products should be prepared without the use of any questionable preservative.

Saccharin is generally employed as a sweetening agent and its use is largely of a deceptive character because the consumer usually believes that when he is eating a food product sweetened with this chemical, that the sweetening is due to some form of sugar. The use of saccharin as a sweetening agent is not only common in food products, but also in medical remedies. Saccharin is a most valuable agent for certain diseased conditions, but this does not justify its indiscriminate use. Inasmuch as deceptions and misrepresentations of all kinds are prohibited under the act, the presence of this chemical should be declared upon the label.

The synthetic production of vanillin undoubtedly was one of the greatest scientific achievements and triumphs of chemistry. Vanillin is a very valuable commodity. It is claimed by many that flavoring preparations made with vanillin as a basis possess distinct advantages over extracts made from the vanilla bean. There is no question whatever but that vanillin possesses certain merits not inherent in the vanilla bean, and it seems rather incomprehensible why manufacturers do not take advantage of this fact and sell vanillin preparations on their merits. Let not vanillin in disguise deprive extract of vanilla of its time honored reputation.

Mechanical and Engineering Section.

Railroad Management and Safety Devices.

By J. C. Irwin,

Superintendent of Construction, Electric Zone, New York Central & Hudson River Railroad Company.

When the subject "Railroad Management and Safety Devices" was assigned to me it appeared so broad that I was at first tempted to ask permission to confine myself to some one detail of this great field, but on second thought it seemed so aptly chosen as a basis for outlining the general subject of safety in railroad operation that it was accepted as offered with the idea of treating especially of the main features of signaling practice at the present time.

The appalling number of serious accidents that has occurred during the last few years and particularly during the last few months has attracted the attention of both the Government and the public at large to questions of railroad management more than ever before. While most of these accidents have occurred either on lines where there was no block system in operation or where the application of the system was so incomplete as to leave great chances for trouble, yet they have not been confined entirely to any one class of railroad, and the list will range from derailments and head-on collisions on lines of light traffic operated under a train order system alone through the various applications of telegraph block and controlled manual signals to occasional cases of rear-end collisions, on account of disregard of signals or derailments through defective equipment occurring under the operation of a highly developed automatic or controlled manual system with complete interlocking at switches.

The records show that by far the largest proportion of accidents is caused by defects in operation, the next by defects in equipment and lastly in track. The line between safe track and dangerous track is pretty clearly drawn. Trouble from equipment

dangerous when applied under service in all kinds of weather and under the varied conditions that arise in actual operation. It requires an expert to select the good from the bad or the best from the next to best.

The general principles of interlocking of switches and signals and the operation of a block system have come to be pretty generally understood. At the time of the Electrical Exhibition of the Franklin Institute in Philadelphia in 1884 a committee of prominent members of the Institute including your Secretary was appointed to report on signaling apparatus. Their able report gives good information to-day on mechanical interlocking and the underlying principles of electrical signaling, including the use of the track circuit for controlling a signal circuit, so that when a train stands on the track section it short circuits the battery, de-energizing the relay and opening the circuit which holds a signal at "clear," causing it to go to "danger."

The principal improvements in recent years have been in the further application of power for operating both switches and signals. The Electro-pneumatic system in which the movements are operated by compressed air at 70-lb. pressure controlled by valves actuated by electricity and the Low Pressure Pneumatic system in which the movements are operated by compressed air at 20-lb. pressure, and controlled by valves operated by air at a still lower pressure, are in many large installations giving way to the All-Electric systems in which all movements are operated by electric power.

The latest complete record of the amount of railroad operated under the block system in this country is for January 1st, 1905. With about 214,000 miles of main line road, at that time about 40,000 miles were operated under some manual system and 5,000 miles under an automatic system. The remainder, most of which was single track, was operated under the train order system.*

In operating under a train order system alone the signals or

*Since the presentation of this paper reports made to the Interstate Commerce Commission in September, 1906, have been published. These show that of 143,615.8 miles of railroad covered by the reports, 48,743.2 miles was operated under some form of block signal. Of this amount 41,916.3 miles was covered by manual signals and 6,826.9 by automatic signals.—J. C. I.

order boards are used at telegraph stations merely to indicate to an engineman whether or not there are orders for him or to remind him of an order to be carried out. The orders given by telegraph are transmitted simultaneously to the offices at which they are to be delivered to the trains concerned in a movement and are directed to the conductor and engineman of those trains. The signal itself merely indicates "stop" or "proceed," but its operation is not connected with that of any signal ahead and the right to the track is conferred by train order.

In operating under a block system the road is divided up into a series of sections called "blocks," the limits of which are defined by fixed signals called "Block Signals," each signal by its indication controlling the use of the block ahead. By fixed signals are meant signals of fixed location indicating a condition affecting the movement of a train.

The block system is operated in one of three forms: The Telegraph, The Controlled Manual and the Automatic systems. In the telegraph block system the signals are operated by hand on information received by telegraph from the operators in the adjoining block stations. In this system the signalman has control of his signals at all times and can clear them at will, there being no mechanical check on him to prevent his giving a clear signal when the block ahead is occupied. By use of electric locks on signal levers, controlled from adjacent block stations, this may be developed into a controlled manual system.

In the controlled manual block system the signals are operated either mechanically or electrically by levers thrown by hand but so locked electrically that it is impossible for a signalman to give a clear signal for a train to proceed into a block without the cooperation of the signalman at the other end of the block. Communication between block stations is by bell code. When used in connection with continuous track circuit the Controlled Manual system gives the benefit of the presence of human intelligence and at the same time by means of electrical and mechanical devices puts it out of the power of the human element to give a clear signal in error. This system is particularly attractive on lines where there are switches and crossovers at frequent intervals requiring the presence of men to operate them.

In the Automatic block system no signalmen are employed, the signals being operated automatically by the passage of a train.

The power for the operation of the signals is supplied either by compressed air or gas or by electric motor, the control in every case being electric.

On account of the great preponderance of single track railroad in this country, one of the most active questions is, how to give the greatest protection on single track without "tying up the road." Automatic signals with continuous track circuit seem to be in most general favor, but there are some very satisfactory installations of the Train Staff system, an improvement on the Staff or Tablet system used in England. This system requires a block station at each end of the section protected, with a staff instrument in each, containing enough "Staffs" or small cylindrical pieces of metal to cover all possible movements of trains in one direction before any would pass in the other direction. Communication between the adjacent block stations is had by bell code, and the staff instruments are so interlocked that if a staff is taken out of an instrument at one end of the section no other can be taken out until it is placed in the instrument at the other end or replaced in the one from which it was taken. The system is operated in connection with a semaphore signal and a staff catcher and deliverer, so that the staff can be delivered to trains running at high speed, the signal being electrically controlled so that it can not give a clear indication unless the staff is in the staff deliverer ready for the train. No train orders are necessary, the right to the track being conferred by the staff. The device has given good results over congested sections of single track.

Every little while there is some new device brought up for giving an indication to an engineman in the cab of his engine, by means of light or bell. These devices are usually designed for use as adjuncts to the outside visual signals. As yet none of them seem to have gotten further than the trial stage.

The question of automatic stops is one that is continually assuming greater prominence mainly on account of the cases where enginemen have run past danger signals on lines with the best of signals maintained to the highest degree. In order for an automatic stop to be valuable, all equipment running over the line must be fitted with the stop device and it must be reliable under all conditions. The most suitable places for its application are those lines with dense traffic where the equipment is confined to a certain district. The Rapid Transit Subway in New York uses a

mechanical automatic stop consisting of a block rising above the rail when the signal is at danger, in a position to trip a valve in the train line of the air brake, stopping the train when the signal is at danger if it is not stopped by the motorman before reaching the signal.

A device known as the Kinsman system picks up current from an electrified track section and guard rail by means of a steel tongue or brush on the locomotive to make the contact, and uses the current to operate an electro magnet releasing a spring which operates a valve in the air brake train line, thus setting the brake, and in addition it uses the pressure of the air released from the train line to operate a piston around the throttle valve of the locomotive and shut off steam.

There will continually be greater opportunities for the application of such devices, when designed and installed in accordance with the best principles of signaling practice.

One of the important questions now under discussion is that of signal indications. Our day signals give their indications by positions and the night signals by color. After many years of settled practice with the downward position of the blade indicating clear, there is now a strong tendency to give the clear signal with the upward inclination, similar to the practice on German railroads. There is good reason for this change, for on account of the weight of the blade it has been necessary to heavily counterweight it in order to insure its remaining at danger in case of broken connections. Along with our other elements in signaling, the downward position of the blade was brought to us from England in the early days of railroading, and while it has been continually recognized by signal engineers that the upward position would be more rational, there has been no movement to make any change until the matter was recently acted upon by the Railroad Signal Association and the Signal Committees of some of the most prominent lines.

There is also diversity of practice in regard to the night indication. For many years white was uniformly the indication for safety or clear, with green for caution and red for danger. As the number of signals increased it came to be realized that in some places, particularly around a city, a multiplicity of white lights gave a chance for an engineman to mistake some other white light for his own clear signal, particularly if the light in his

signal happened to be out. There was also a chance for the breaking of a red lens in a danger signal to leave a white light indicating clear when the conditions called for a danger indication.

These conditions started the practice of using green for clear and an amber light for caution, leaving the red as a danger signal. Where white is still used for a clear indication, the practice is to make the red lens much heavier and tougher than was formerly done, eliminating the question of breakage.

It could not be within the scope of this paper to cover all of the valuable and interesting applications of signaling and its associated safety devices for the protection of traffic against obstructions or openings in the track, but as an example of the most highly developed signal practice at the present time, there may be given a description of the signal system now being installed in the "Electric Zone" covering the New York suburban district of the New York Central & Hudson River Railroad.

Besides being the largest signal contract ever awarded, this work represents an important advance in the art of signaling. Both block and interlocking work will be all-electric, operated by current taken from a power line running the whole length of the system. All track and signal circuits will be operated by alternating current; the only batteries to be used will be storage batteries for the operation of interlockings, which will be charged by an a.c-d.c. motor generator drawing current from the power line. In comparing proposals, the New York Central Railroad Company gave special consideration to safety and reliability and economy of operation, and also to quickness of delivery and erection, and the selection of this system was made only after the most systematic and careful deliberation.

At terminals and on short sections at interlockings, it was practicable to give up one of the rails of each track for signaling purposes, but for the greater part of the system it was of considerable advantage to the electric traction system to allow both rails of each track to be used for the return current.

The system offered by the General Railway Signal Company, and known as the "Young System," was adopted. Alternating current is used for track circuits in connection with reactance bonds, permitting the passage of the direct propulsion current freely through both of the running rails, while preventing the

flow of the alternating current which is used in signaling. This two-rail system was deemed best suited to the conditions.

Track plans showing the spacing and arrangement of all signals were prepared by the railroad company, and together with specifications were submitted to all the signal companies capable of handling the work. Separate bids were requested for the block signaling and the interlocking work.

To assist in finally deciding the system to be adopted, bids for block signaling were requested in eight different forms covering both normal clear and normal danger systems, all-electric and electro-pneumatic design, and either with one rail of each track given up for signaling purposes or with both rails left available for power return. Bidders were encouraged to make suggestions as to design and requirements of specifications, so that the specifications might not be considered to act as a restriction on the exercise of their best skill. In canvassing the proposals the Signal Committee of the New York Central Lines was called into consultation, and every feature was gone over in detail.

The work included by the contract covers what is known as the electric zone, extending from the Grand Central Station to Croton, on the Hudson Division, a distance of thirty-five miles, and from Mott Haven to White Plains, on the Harlem Division, a distance of nineteen miles. Throughout this distance there will be four main tracks, and the work includes about 3000 interlocking levers and 1400 track circuits, aggregating about 250 miles. The work to be undertaken at the present time covers only that portion of the road to be electrified this year, which carries the work from the Grand Central Station to High Bridge, on the Hudson Division, and to Wakefield, on the Harlem Division.

Power for operating the signal system will be taken from the two main power stations of the company at Port Morris and Yonkers, which deliver three-phase alternating current of 25 cycles and 11,000 volts, and from the various sub-stations which deliver direct current at 666 volts to the third rail for operating purposes. These sub-stations are also equipped with the transformers for the signal service, delivering alternating current at 3000 volts to the signal transmission line, which although extending the entire length of the district to be signaled, is cut half way between each pair of sub-stations, thus making that portion

of the line fed by each sub-station entirely independent of the adjoining one.

The apparatus in each sub-station is properly protected with automatic and hand-operated switches, and to insure operation, should the alternating current fail, d.c.-a.c. motor generators taking current from the storage battery system installed in each sub-station for use of traffic, will continue to feed the signal transmission line with alternating current, and the signal system will continue to work under all conditions under which traffic will be operated. A synchronizer is installed between the transformer and the motor-generator set.

The 3000-volt transmission line consists of No. 0 bare copper wire, carried on the pole line and in the conduits used for the main transmission system, and the signal bridges are equipped with extension brackets, with cross arms, for convenience in running wire lines to signals.

For the operation of signal circuits, signal motors, indicators, and signal lighting, the 3000-volt current is stepped down 50 volts, through transformers placed on signal bridges or transmission line poles. The secondary of the transformer is provided with a ground connection, formed by burying a 2-ft. x 3-ft. x 1-16-in. copper plate, to which is brazed a No. 4 B. & S. gage copper wire.

For track circuit operation the voltage depends on the length of track circuits, and varies from 1½ volts for circuits of 200 ft. to 8 volts for circuits of 5000 ft. The reduction from 50 volts to the track voltage is made by a transformer provided with four taps, which will permit of one type of transformer being used on all track circuits.

In laying out the block signaling plan, the length of the block was determined by the braking distance. For speeds not exceeding 45 miles per hour the blocks were made 1200 feet long; for speeds between 45 and 60 miles per hour, 2500 feet, and for speeds over 60 miles per hour, 3000 feet, the average length of the long blocks being about 3200 feet. All blocks have a full block overlap. A distant signal is provided for each home signal. On account of the density of traffic and the necessity for quick operation the clearing time of signals is limited to three seconds.

The track circuits are of three types. Where they are 500 feet or less in length, and where the drop in potential in the

length of the track circuits is not greater than 50 volts, the "one-rail" system is used, and one rail of the track is given up for signaling purposes. There being no direct current on the signal rail it is not necessary to use any reactance bonds.

On all track circuits over 500 ft. in length, the two-rail system is used, and both track rails are employed for the return of the direct power current. On all of these circuits it is necessary to use the reactance bonds, by which the connection is made around the insulated rail joints, permitting the direct current used in operating to pass, while impeding the alternating current used for track circuit work. The insulated rail joints are of the Weber pattern, with a steel angle plate on the inside.

On track circuits between 500 ft. and 1600 ft. in length the two-rail system is also used, and the reactance bonds consist of a copper bar 1 in. in cross section and 30 ft. long coiled in eight turns around an iron core.

It will be seen that the block sections are of two types, the one-rail and the two-rail systems. In the former the propulsion current flows along the continuous rail, and in the event of a defect in the continuous rail, this current must avail itself of the conductivity of adjacent tracks, through the cross bonding.

In sections of the two-rail system each of the traffic rails of a track forms separate and independent conductors, so that if one rail is interrupted, the other would act as a return conductor, even if there were no cross-bonding to adjacent tracks.

The use of two styles of bonding was determined by the cross-bonding for the electric traction system. The Engineering Department of the railroad company determined that the distance between such cross-bonds should not exceed 1600 ft. For blocks that are 1600 ft. or less in length the type of bond, allowing cross-bonding at the ends of the track sections, was best suited to the conditions. For track circuits over 1600 ft. in length, where a cross-bond between one rail of each track was required every 1600 ft., the ironless reactance bond is the least expensive and the one to be used.

All of the reactance bonds are enclosed in water-tight cast-iron boxes, set on foundations, and the boxes are filled with oil to carry off the heat generated. The bond is designed to permit the continuous passage of 3000 amperes for each rail of the track without injurious heating. The casing of the box is made to cover

the terminals and connections to the rail to keep them from being tampered with.

The track relay is of the induction motor type with two field coils. One coil is energized by the 50-volt signal operating current which gives the greater part of the energy required to magnetize the fields and armature. The other coil is energized by the current from the track rails, and this current need only be strong enough to give sufficient magnetism to rotate the armature. The armature revolves through an angle of $37\frac{1}{2}$ deg., during which movement the contacts are separated through $23\frac{1}{2}$ deg., and made up through 14 deg., thus giving a good rubbing contact. Especially hard carbon is used for the fixed point of the contact, while the moving point is of platinum. As the controlled current is an alternating one, there is little sparking, although currents of from 2 to 3 amps. are used.

The box containing the track relay and transformer and the grid resistance has a plug in which an electric light can be cut in for use in night inspection.

The signals are to be of the General Railway Signal Company's motor-operated type, with mechanism placed in the base of the signal mast, and worked by a single-phase alternating motor of $\frac{1}{4}$ hp, using current at 50 volts. The slot mechanism is exceedingly simple, and under alternating current operation is very quick in releasing.

The signals are of the 60-deg. two-position type, using New York Central standard spectacles and blades, which impose on the signal motor a load equal to the lifting of a 17-lb. weight, at a distance of 4 ft. from the center of the shaft. With this load the motor will clear the signal in from two to three seconds. The New York Central Standard signal blades have square ends for home signals at interlockings, and pointed end blades on automatic home-block signals. The signal lamps are of 4 cp, working on a 50-volt circuit, and are connected in parallel with a fuse cut out, to allow any lamp to be disconnected, without affecting other lamps supplied on the same circuit. The filament of the lamp is wound in a small circle, to bring the point of maximum illumination within the focus of the lens.

The signals to be used in the Park Avenue tunnel will consist of lights only, without any moving parts whatever. Electric lights will be arranged in a box behind lenses of proper color, and

the current for the lamps will be directly controlled by the relay contact. Lamps giving the proper color for the stop or caution indication will be lighted when the track relay contact is closed.

With this installation the colors used by the New York Central for the night signal indication will be changed in the electric zone, and instead of using white for proceed and green for caution, the system of using green for proceed and yellow for caution will be used for the first time on this line.

The interlockings are of the standard type, manufactured by the General Railway Signal Company. Direct current furnished from storage batteries is used to operate the switch movement and signals. As usual with this type of apparatus the indication is given by the current formed by the motor, which on completing its stroke at the signal or switch movement, is changed to a generator and gives sufficient current to release the lock of the lever of the machine.

The current to change these storage batteries will be obtained from an a.c-d.c. motor generator set, taking current from a transformer fed from the 3000-volt signal transmission line and furnishing current of 150 volts. The storage battery consists of fifty-five cells of capacity varying from 80 amp-hours to 320 amp-hours, according to the number of daily lever movements to be made. The average time between charging will be four days. The motor generators with switchboards will be placed in the basement of tower buildings and a separate battery-house will be provided to keep the fumes of the batteries away from the signalmen and the apparatus in the towers.

The interlocking machines are of the usual type made by the General Railway Signal Company, and are provided with a latch for each lever to require a definite action on the part of the operator to change the position of the lever. The lever handles are colored according to their functions. There will be a separate lever for each high signal arm and no selectors will be used.

The interlocking signals will be of the General Railway Signal Company type with dynamic indication current return. These signals, where slotted, will return to the stop position when the current through the slot magnet is open, but the return indication from the signal motor is not received at the lever until the lever is restored to the normal position. The operating circuits for the signals are run through controllers on all facing switches in the

main line, insuring that the switches are properly set before the signals can be cleared.

Block signals on the same mast with distant signals are controlled by a lever in the machine requiring the block signal to be changed to the stop position before a signal can be cleared for a reverse movement on the main line.

The advance signals for each track, although operating as automatic block signals, are controlled from the interlocking and are provided with a square end blade to enable the signal man to hold a train, if it is desired to do so.

Approach locking will be provided for all main-line switches. This locking becomes effective when a train has reached a point at least one mile in the rear of the distant signal.

To permit the signal man to change the route for a train, in case of a mistake in setting it up, a mechanical screw release is provided. This will allow the release of the lever and changing the route on the expiration of a time interval of 1½ minutes after the signals have been returned to the stop position. A counter reading to five figures is to be placed on all high signals to register the number of movements.

The movement to be used to operate the switches is of an entirely new type. With the small clearance under the third-rail contact shoe, a mechanism that will not project above the top of the running rail is absolutely necessary. This movement is enclosed in a neat casing with the gear and escapement crank horizontally arranged. The reversible pole changer and indication switchbox are also enclosed in the casing with the switch mechanism, protecting these parts and giving an exceedingly neat appearance to the apparatus.

The movement is fitted with an improved locking device which, in the case of the plunger catching on the locking rod, as it will do if the switch does not lock up properly, will release the plunger, allowing it to stop while the main part of the movement completes its stroke. The arrangement prevents the motor from forcing the plunger through the lock rod in case it should not have come to the proper position.

The type of dwarf signal to be used is a new one, the signal arm being moved to a motor mechanism arranged horizontally at the base of the post. With this apparatus the indication will be returned to the lever by the current generated by the motor in-

stead of by battery current, as is required with a solenoid mechanism.

In this installation the use of detector bars is practically abolished, a few only being used on the outside rail on sharp curves. Short electric track circuits are provided in their place, effecting the locking of the switches during train movements by controlling the locks on the switch levers. The use of these short-track circuits with the controlling wires to the interlocking machine, makes possible at small expense the use in the interlocking tower of illuminated track indicator. It will consist of a track plan of the interlocking painted on a piece of ground glass with the track circuit sections divided on the back of the glass into separate compartments in which are a red and a white electric light. When the track section is occupied a red light will be shown on the indicator plan, and when unoccupied a white light will be shown.

In places like the Grand Central Terminal, where the tracks will be entirely roofed over, it will not be possible for the signal man to observe the movements of many of the trains; and an indicator of this kind is an absolute necessity to enable him to keep in touch with the situation. As in the Park Avenue tunnel, the signals in the Grand Central Station interlocking will be shown entirely by lights without any blades or moving parts. In this interlocking work, however, the lever for the signal completes the circuit for the lamps to give the proper color for the indication required.

This detailed description of an important installation gives an idea of the progress in signaling practice in connection with electric traction. The main cry of the country, however, is for the extension of the block system and its allied safety devices over lines not properly protected and wide-awake supervision both for maintenance and operation that will get the best results out of the apparatus provided.

Book Notices.

PUBLICATIONS RECEIVED.

Michigan College of Mines. Year Book, 1905-1906. 131 pages, 12mo. Views at the Michigan College of Mines, Supplement to the College Year Book. Twenty-five illustrations, showing the exterior and interior of the college buildings and the students at work. Oblong, 24mo. Houghton, Mich. The College, 1906.

Transcœrsal-Dampfturbinen für elastiche Kraftnittel: Wasserdampf, Luft, schweflige Säure, Kraftgas u. dgl. von A. Patschke, Ingenieur in Mülheim a d. Ruhr. Ed. 1. 73 pages, plates, 8vo. Mülheim, Max Röder, 1904. Paper. Price, 2.50 marks.

Index to the Transactions and Journal of the New England Water Works Association, to December, 1903, inclusive. 115 pages, 8vo. Boston. New England Water Works Association, n. d.

U. S. Department of Agriculture, Weather Bureau, Bulletin Q. Climatology of the United States, by Alfred Judson Henry, Professor of Meteorology. Prepared under the direction of Willis L. Moore, Chief U. S. Weather Bureau. 1012 pages, maps, Q. Washington. Government Printing Office, 1906.

Sections.

ELECTRICAL SECTION.—*Stated Meeting* held Thursday, November 22d, at 8 P.M., Mr. Thomas Spencer in the chair. Present, twelve members and visitors. The President introduced Mr. James B. Hoge, of Cleveland, President of the International Independent Telephone Association, who presented an interesting communication on the Development of Independent Telephone Lines. The paper was discussed by Messrs E. Alex. Scott, W. C. L. Eglin, H. F. Colvin and the author.

The thanks of the meeting were voted to the speaker of the evening, and the meeting was adjourned.

WM. H. WAHL, *Sec'y pro tem.*

Stated Meeting, held Thursday, January 24, 8 P.M., Mr. Spencer in the chair. Present, forty-eight members and visitors. Mr. H. I. Mauger. General Electric Company, gave an informal address on the subject of "Electricity in the Home," which he illustrated by the exhibition of a considerable outfit of electric heating and cooking appliances and with a collection of lantern photographs exhibiting views of buildings completely equipped with fixtures and appliances for utilizing electricity for domestic purposes.

The speak r expressed his belief that within a few years the installation of an electrical equipment in new dwellings would become universal.

The subject was freely discussed. Adjourned.

WM. H. WAHL, *Sec'y pro tem.*

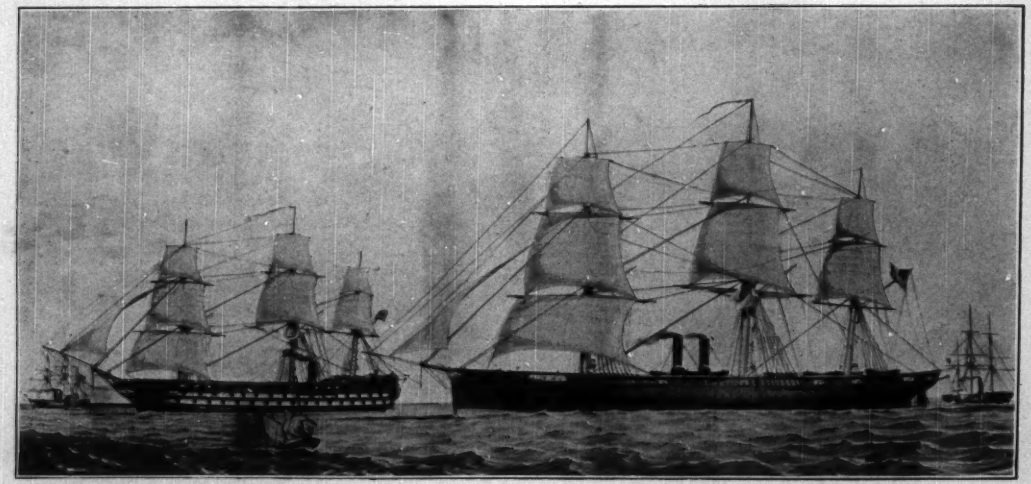
SECTION OF PHYSICS AND CHEMISTRY.—A meeting of this Section was held on Thursday, January 10th, at 8 o'clock P.M. The President, Dr. Robt. H. Bradbury, in the chair., Present, thirty members and visitors.

The President introduced Mr. Lyman F. Kebler, chief of the Drug Laboratory, U. S. Dept of Agriculture, who read a paper on "Synthetic Chemicals." The paper was freely discussed by Dr. Edward Goldsmith, Prof. Remington, Mr. M. I. Wilbert and the author.

A vote of thanks was passed to the speaker of the evening.

Adjourned.

EDWARD A. PARTRIDGE, *Sec'y*



The First Atlantic Telegraph Cable Fleet.

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